BIODIVERSITY, CLIMATE CHANGE AND ENVIRONMENTAL IMAPCT ASSESSMENT

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General introduction

During the last century, the natural environment has globally been facing an enormous number of significant human-induced impacts such as habitat destruction, habitat fragmentation and pollution that threaten the long-term survival of biodiversity (Sala et al. 2000). In addition, the anthropogenically induced increase of atmospheric CO_2 and concomitant release of methane is causing the recent climate change (IPPC 2007) that increasingly might influence global biodiversity patterns (Botkin et al. 2007; Colwell et. al. 2008).

It is proven that the growing human population is resulting in growing demands on resources e.g. by implementation of new developmental projects (Reid 1995). Hence, there is growing concern amongst many natural scientists that human interventions are altering the capacity of ecosystems to provide goods and services (Balvanera et al. 2006, Fargione et al. 2006). To control the negative impacts resulting from developmental projects, special attention has to be paid before starting new projects to predict their impacts. Developmental projects should be implemented in a sustainable way that is both responsive to population demands as well as protective towards resources not only in the present, but also in the future (UN 1987). Hence, there should be a balance between the economical benefits of a project and the damages it will produce (Munier 2004). Environmental Impact Assessment (EIA) is a decision-making tool aiming to achieve this balance and to ensure that project options under consideration are environmentally sound and sustainable (World Bank 1999). Article 14 of the Convention on Biological Diversity (CBD) requires parties to apply environmental impact assessments to projects that potentially negatively impact biodiversity (CBD 2001, Slootweg and Kolhoff 2003). However, to date, few EIA processes include predicted climate change as an environmental consideration either as a factor in assessing the impact of the project on the environment, or as a possible impact of the environment (i.e. the climate) on the project (CAEE 2003).

In my PhD thesis, I conducted both an observational study on the effects of climate change on the biodiversity of fen meadows in Switzerland as well as a practical review, evaluation and assessment of the EIA legal basis and the effectiveness of environmental impact statements in Iran.

Environmental Impact Assessment (EIA)

In the late 1960s, EIA was conceived as a decision tool in response to increasing environmental concerns. It was aiming to balance between technocentric needs while overcoming environmental problems (Petts 1999, El-FAdl 2004). Based on the IAIA (International Association for Impact Assessment; www.IAIA.org) definition, an EIA is "the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made." The objectives of EIA addressed by the IAIA are:

• to ensure that environmental considerations are explicitly addressed and incorporated into the development decision making process;

• to anticipate and avoid, minimize or offset the adverse significant biophysical, social and other relevant effects of development proposals;

• to protect the productivity and capacity of natural systems and the ecological processes, which maintain their functions; and

• to promote development that is sustainable and optimizes resource use and management opportunities.

Often, all findings of an environmental impact assessment are getting documented in a Environmental Impact Statement (EIS). A statement which is mainly documenting 'socio-economic' impacts is called SEIS. In this study, we focused on the EISs.

The quality of the EISs are playing a vital role in decision making processes and can be used as an indicator of the effectiveness of environmental impact assessments (Morrison-Saunders et al. 2001; Barker and Wood, 1999).

The effectiveness of an EIA system depends on its legal basis (e.g. legislations and guidelines) and how effective the impact assessment (documented in EIS) has been carried out. In this study, we evaluated the Iranian EIA system focusing on the legal basis as well as on its effectiveness based on an analysis of environmental impact statements (EISs) of EIA conducted in Iran 1996–2006.

Environmental change and biodiversity

To date, climate change is considered the second biggest driver of biodiversity change globally and the first for alpine ecosystems in the next decades (Sala et al. 2000). Europe is forecasted to experience between 2.2–5.1°C rise of temperature until 2100 (IPCC 2007).

This change will have an impact on plant biodiversity (Lenoir et al. 2008) particularly on mountainous ecosystems (Thuiller et al. 2005). Plant species have to persist in the changed climate, migrate to a more suitable climate, or get extinct (Bazzaz 1996, Theurillat and Guisan 2001). Some plant species appear to be constrained in moving along with the changing climate, others adapt well or move easily and prosper in their new environmental conditions. As changes in climate occur concomitantly with other environmental change caused by human impacts (Botkin et al. 2007) such as fragmentation and pollution (for example by nitrogen deposition; Sala et al. 2000, Stockwell et al. 2003, Jump and Penuelas 2005, Thuiller 2007) the plant ecological groups potentially adapted to a changed climate might, however, still be at risk if they do not have the potential to cope with multifactorial environmental change.

In this thesis, the changes in plant diversity of pre-alpine fen meadows of Switzerland have been studied over the last 10 years. We analysed whether biodiversity patterns and species densities of different ecological groups (e.g. fen specialist species, thermophilous species, shade indicators, early or later flowering plants) changed within traditionally managed semi-natural ecosystems despite protection efforts.

In parallel to this thesis, Sima Fakheran, in her Ph.D. dissertation addressed the landscape's spatial patterns and their effect on ecological processes in these protected fen meadows within the last 10 years.

Outline of the dissertation

Following this introductory chapter, the thesis is composed of 4 chapters. The first two chapters describe effects of functional traits and different plant-species groups' responses (colonization and extinction rates) to climate change and the effect of management type on biodiversity of species-rich fen meadows of the foothills of Swiss Alps. The last two chapters describe the evaluation of the Iranian EIA system using environmental and EIA laws and guidelines and examine the overall effectiveness of 96 environmental impact statements conducted within the Iranian EIA system.

Chapter 2 focuses on the responses of different plant functional groups in fen meadows to climate change. We specifically investigated whether 1) species density changed by altitudinal changes within a 10-year period, and if so, 2) which functional class (i.e. fen specialist species, thermophilous species, shade indicators, early or later flowering plants) responded positively or negatively over time and, 3) whether changes in species density of any group were correlated with changes in abiotic soil variables or with community-level changes e.g. in biomass production. We investigate these changes over a 10-year period by using the data derived from 180 plots of $2m^2$ (36 fen meadows with 5 plots each). These analyses have been carried out at the site level (cumulative data from five plots per site).

Chapter 3 considers recent trends in species density of both vascular plants and bryophytes, and aims to identify possible underlying environmental causes of vegetation change. We particularly assessed 1) whether diversity of species of high conservation concern and habitat quality was maintained in the traditionally managed areas, and 2) whether species turnover over a 10-y time span and changes in habitat quality differed between the two traditional management regimes grazing and mowing. We investigate these changes over a 10-year period by using the data derived from 180 plots of $2m^2$ (36 fen meadows x 5 plot each). In this study, small-scale vegetation changes at the plot level were analyzed.

Chapter 4 analyzes the EIA system in Iran. The provisions for EIA in Iran were adopted in 1994 (DoE 2004). To date, many evaluations of the legal basis of different EIA systems around the world have been carried out (Wood and Coppel 1999; Glasson et al, 2000; Appiah-Opoku 2001; Bektashi and Cherp 2002; Ahmad and Wood 2002; Glasson 2003; Briffett et al. 2004; Ahammed and Harvey 2004; Ogunba 2004; Canelas et al. 2005; Coskun 2005; Paliwal 2006), but the Iranian EIA system has not been evaluated so far. Iran is an immense country with diverse climatic and environmental conditions harboring a vast diversity of terrestrial and marine species. Many Iranian ecosystems are of international importance and declared as biosphere reserves. Therefore intense environmental protection in Iran is of global importance. Environmental impact assessment by itself is playing an important role in environmental protection. We applied the evaluation criteria developed by Wood (2003) to evaluate the effectiveness of the legal basis (laws and guidelines) of the Iranian EIA system. We used these criteria to identify gaps in all 14 individual stages of an EIA system such as legal basis, coverage, consideration of alternatives, screening, scoping, report contents, report review, decision making, impact monitoring, mitigation measures, consultation and public participation, system monitoring, cost and benefits and Strategic Environmental Assessment (SEA). Based on our analysis, we give recommendations on how to improve the effectiveness of the EIA system in Iran.

Chapter 5 examines the overall effectiveness of the 96 selected Environmental Impact Statements, belonging to 17 different project types such as ‘Dams’, ‘Cement plants’, ‘Mineral extraction’, ‘Landfills’, ‘Power plants’, ‘Refineries’ and ‘Steel melting plants’, in Iranian EIAs. We carried out a quality assessment of methodologies used for EIAs and scrutinized the especially critical sections ‘Scoping’, ‘Mitigation plan’ and ‘Monitoring plan’. We compiled different evaluation checklists for different sections of the EISs. The checklists contain all the potential environmental impacts, mitigation measures and monitoring actions, which are expected to be considered in the EIA process. Effectiveness was judged based on calculating the percentage of the identified impacts, suggested mitigation measures and recommended monitoring actions out of the expected ones in each 17 project types. Using these checklists, we examined: 1) which ecosystems as well as which designated areas and wildlife species are most likely affected by potential projects; 2) how biological impacts vs. physical impacts of the potential projects have been predicted and evaluated; and, 3) how biological parameters vs. physical parameters in monitoring plans have been considered. In addition, 4) we tested whether the accuracy of predicted impacts and the conservation value of mitigation as well as monitoring plans have increased from 1996–2006. We calculated the effectiveness of the sections and sub-sections of the EISs by evaluation checklists with Bayesian network analyses. By conducting sensitivity analyses for the Bayesian networks, we checked how the effectiveness of sections and subsections can influence the overall effectiveness of the studied sections of the EISs.

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Range expansions of warm-temperature and generalist plant species in the Swiss Alps from 1995–2006

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Abstract

It is forecasted that Northern Europe will experience a rise in temperature of between 2.3–5.3°C from now until 2100. This increase in temperature will most probably lead to changes in species composition. Such changes have already been observed over the recent decade in high altitude or high latitude ecosystems. We conducted a comparative field study over ten years on the changes in vegetation composition in protected, species-rich fen meadows in the foothills of the Swiss Alps (800–1400 m a.s.l.). From 1995–2005/06, species density per site of all vascular plants increased. However, whereas species numbers of putative profiteers of climate change and other environmental change increased during that time period, fen specialists significantly declined in species numbers. The main shift in vegetation composition occurred at the low altitude sites, which overall had a higher colonization rate than higher altitude sites. Especially warm-temperature species colonized more often than they went extinct. Early-flowering species had a high colonization rate in grazed, but not in mown fens and especially colonized low-altitude grazed fens. Species with low habitat-specificity had a high colonization rate at low-altitude mown fens. Finally, a large number of shade indicators colonized sites at all altitudinal levels, presumably due to increased community biomass and therefore shading. During the observation period, our fen sites increased in productivity, although soil concentrations of NO_3^- and PO_4^{3-} did not change significantly. We conclude that the observed changes in plant species distributions at our field sites, especially the increases in warm-temperature and generalist species, was probably mainly due to an increase in temperature and prolonged vegetation period.

Key words: range expansion, multi-factorial environmental change, climate change, colonization rate, biodiversity, plant functional groups, ecological indicators

Introduction

Evidence is increasing that the rising concentration of greenhouse gases in the atmosphere may lead to significant changes in the European climate (Houghton *et al.*, 2001). Northern Europe is forecasted to experience a rise in temperature of between 2.3-5.3°C from now until 2100 (Christensen *et al.,* 2007,); and also temperature extremes, i.e. temperature minima and maxima are predicted to increase considerably by the end of the 21st century (Kjellstrom *et al.,* 2007). In Switzerland for example, an increase in anomalies of monthly temperatures from 1941–2000 has been observed in comparison with a previous period of 1864–1923 (Schär *et al.,* 2004) and the mean annual temperature have increased by 0.4°C per decade since 1961 and consequently from 1970–2006 the mean temperature has increased in total by 1.5°C (North *et al.,* 2007). Such drastic climatic changes could have an impact on plant diversity (Thomas *et al.,* 2004; Lenoir *et al.,* 2008) with mountainous regions having a high risk of loosing species (Thuiller *et al.,* 2005). Earlier warming events in history causing relatively smooth upwards shifts in the vegetation had a much slower rate of climate change of e.g. 1°C warming per century in the Peruvian Andes during the Pleistocene-Holocene warming (Bush *et al.,* 2004). Hence, to date climate change is considered the second biggest driver of biodiversity change globally and the first for alpine ecosystems in the next decades (Sala *et al.,* 2000).

There are three basic ways in which species may respond to climatic change (Bazzaz, 1996; Theurillat & Guisan, 2001): (i) persistence in the changed climate, (ii) migration to a more suitable climate, or (iii) extinction. Recent analyses indicate that some species are already responding to changing climatic conditions by expanding or contracting their ranges (Grabherr *et al.,* 1994; Fitter & Fitter, 2002; Parmesan & Yohe, 2003; Root *et al.,* 2003; Walther *et al.,* 2005; Wilson *et al.,* 2005; Pauli *et al.,* 2007; Lenoir *et al.,* 2008). Whereas some plant species appear to be constrained in moving along with the changing climate, others adapt well or move easily and prosper in their new areas. To date, we lack good hypotheses to explain these differences in migration and establishment potential of plant species along altitudinal (Grabherr *et al.,* 1994; Lenoir *et al.,* 2008) or latitudinal gradients (Tamis *et al.,* 2005). However, a range of plant functional types that may be differentially influenced by climate warming has already been identified or postulated: 1) early-flowering species (Fitter & Fitter, 2002) profiting from an earlier start of the vegetation period; 2) late-flowering species (seed riskers; Molau, 1993; Theurillat & Guisan, 2001) that profit from longer vegetation periods; 3) “guerrilla” species, i.e. clonal species capable of rapid range expansion; 4) fast-growing species that are invaders elsewhere and might be herbivore-limited in their present range; 5) herbaceous plants (as opposed to woody plants; Theurillat & Guisan, 2001) or, in general, species with a fast life cycle (Lenoir *et al.,* 2008). As changes in climate occur concomitantly with other environmental change caused by human impacts (Botkin *et al.,* 2007) such as fragmentation and pollution (for example by nitrogen deposition; Sala *et al.*, 2000; Stockwell *et al.*, 2003; Jump & Penuelas, 2005; Thuiller, 2007) these ecological groups, however, might still be at risk if they do not have the potential to cope with multi-factorial environmental change. Besides the individual species’ fitness responses, some experiments have shown a response at the ecosystem level e.g. by changes in net primary productivity, mainly in combination with other drivers of global change such as CO_2: for example, Riedo *et al.* (1997) have shown an increase of community biomass production by 8% in response to increasing temperature alone and by 6–20% in response to a combination of increased temperature and elevated CO_2.

In 1995, we conducted a comparative field study on the effects of altitude and management type (grazing vs. mowing) on wetland biodiversity using a network of 36 calcareous fen sites identifiable by their typical *Carex davalliana* vegetation type (Wettstein & Schmid, 1999; Bergamini *et al.*, 2001a, 2001b; Pauli *et al.*, 2002; Peintinger *et al.*, 2003). These fens were selected according to stratified random sampling from an inventory of 309 listed calcareous wetlands in the eastern pre-alpine region (800–1400 m a.s.l.) of Switzerland (BUWAL, 1990; Bergamini *et al.,* 2009). To screen for possible shifts in species ranges, we repeated all vegetation surveys and measurements of soil abiotic variables in 2005/06. By this re-investigation after a decade, we investigated putative changes in vascular plant species richness and species presence/absence within four different functional classes broadly defined as general indicators of habitat change, climate-change indicators, soil-quality change indicators, and community-productivity change indicators.

Specifically, we investigated whether 1) species density changed at the different altitudinal levels within the 10-year period, and if so, 2) which functional class responded positively or negatively and, 3) whether changes in species density of any group were correlated with changes in abiotic soil variables or with community-level changes e.g. in biomass production.

Materials and methods

Study sites and vegetation monitoring

We randomly selected 36 fen meadows in central and north-eastern Switzerland out of a total of 309 fens in this area listed in a national inventory (BUWAL, 1990; Bergamini *et al.*, 2009; Fig. 1). These fen meadows were classified into three altitudinal classes (800–1000, >1000–1200, >1200–1400 m a.s.l.). Our selection was based on an equal distribution of fens under two traditional management regimes (mowing once a year in mid-September or grazing by cows) and was done in a way to avoid a confounding of site area with the factors management and altitude (see Bergamini *et al.*, 2001b).

Calcareous fens belong to the most species-rich grasslands in Europe (Ellenberg, 1996) and contain many rare plant species (Wettstein & Schmid, 1999; Pauli *et al.*, 2002; Bergamini *et al.*, 2001a) that are adapted to the nutrient-poor and moist site conditions (Dietl, 1975). In Switzerland, all fens of national importance are legally protected since 1987 (Grünig, 1994) and for most sites, management contracts exist that should ensure an appropriate conservation management (BUWAL, 2002). Therefore, protected fen meadows are not artificially fertilized and either only mown in early autumn or non-intensively grazed. We surveyed these montane calcareous fens of the phytosociological alliance *Caricion davallianae* (Ellenberg, 1996) twice over a decade. Vascular plant species presence and abundance was assessed in five randomly selected 1 x 2 m plots per site in summer 1995 and 2005 (24 fens) and July 2006 (12 fens). Shape and size of plots in the second survey (2005/06) were identical to the first survey (1995; see Bergamini *et al.*, 2009, for a detailed description of the monitoring process). Species absence/presence data were used to calculate the cumulative species density at site level, i.e. at the level of the 5 plots per site (in total 10 m^2). As the management changed in one of the mid-altitudinal sites from grazing to mowing within the study period, we excluded this site for the comparisons of species compositional change.

Classification of plant species into groups

The vascular plant species recorded were classified in different groups based on phenological and ecological characteristics putatively influenced by climate and other environmental drivers. A complete list of all groups defined is provided in Table 1. Generally, groups were mutually non-exclusive with the exception of fen specialists: none of the fen specialist species was a warm-temperature species or shade indicator and with one exception of a species that also occurs in calcareous dry grasslands, fen specialists were not grouped among the species with low habitat specificity (Table S1). Based on these groups, the differential change in species number of each group vs. all other species over the 10–year period was calculated.

The taxonomy followed Fischer *et al.* (2005). Most morphological and ecological data were obtained from Landolt (1977) using ecological indicator values for vascular plants occurring in Switzerland. Landolt's indicator values range from 1–5 on an ordinal scale (low numbers represent low, high numbers high requirements; Table 1). Indicator values have been shown to be an integrative tool for measuring habitat quality (Diekmann, 2003) and allow a useful characterization of species into functional groups (Voigt *et al.*, 2007). For the habitat specificity scoring (Table 1), values of habitat specificity between "low" vs. "medium to high habitat specificity" were assigned to species by counting the number of phytosociological orders in which they occur in Switzerland according to the literature (see Fischer & Stöcklin, 1997 and Joshi *et al.*, 2006 for a detailed description of the specificity scoring). The phenological grouping of species was based on flowering data obtained from a Swiss Flora (Lauber & Wagner, 1996; Table 1). Species were considered clonal if they can produce rooted ramets (Rothmaler, 1991; Table S1).

Abiotic environmental conditions

Abiotic site variables were recorded at each site. Soil nutrient analyses were done for two plots per site in 1995 and 2005/06; pH was measured in four plots per site in 1995 and in five plots per site in 2005/06. In 1995, from each plot, two soil cores were taken (6 cm diameter, 10 cm depth) and in 2005/06, one soil core was taken per plot (6 cm diameter, 10 cm depth). The soil was dried at 70ºC to constant weight. NO_3^- and PO_4^{3-} were analyzed by standard methods (Anonymous, 1997, 2004). The soil pH was measured from water suspension 1:3 soil/deionizer water (w/v) with a pH-meter (Knick 761 Calimatic, Knick, Berlin, Germany). Total N was determined using a CHNS-Analyzer (LECO-932, St. Joseph, Mich. USA). In preparing soil samples, a slight change occurred in the second survey as in contrast to the first survey, fine roots were carefully removed from soil samples by using a fine sieve (0.5 mm mesh) after grinding. Therefore, in the statistical analysis, the "date of survey" effect contains a bias toward higher amounts of fine-root material and thus nutrients in soil samples from 1995, but we assumed that the interactions of date of survey with altitude and management should not be affected by this bias. To overcome the bias problem, we thus tested whether the changes in soil variables per site after a 10-year period were significantly correlated with differences in extinction and colonization rates.

To assess putative climatic trends, we used records of daily mean, minimum and maximum temperatures collected by the Swiss Federal Office of Meteorology and Climatology between 1959–2006 at three weather stations within our research area (Einsiedeln: 910 m a.s.l., Ebnat-Kappel: 623 m a.s.l., St. Gallen: 779 m a.s.l.). Because of missing data for some years in some stations, we only analyzed the period for which data were available for all three stations (daily means since 1959, daily minimum temperatures since 1971 and daily maximum temperatures since 1976). Based on daily mean and minimum temperatures, the length of the vegetation period (VP) was calculated: the beginning of the VP was estimated as at least 7 consecutive days with mean temperatures ≥ 5°C. The end of the VP was determined with at least 5 consecutive days with daily minimum temperatures ≤ 4°C or one day with minimum temperature ≤ –2°C (Primault, 1992). Because of missing data for minimum temperatures at the Ebnat-Kappel station, the beginning of the VP was calculated since 1959 and the end and total length of the vegetation period since 1971, respectively. To analyze changes in the vegetation period, we used the average of the beginning, end, and length of the vegetation period across the three stations. The linear effect of "year" was tested against the residual variation among years.

From 1959–2006, the average daily mean temperature per year measured at the three stations increased by 0.98ºC ($F_{1,45}$=10.56, P=0.002; Fig. 2). The daily minimum temperature increased by 1.08ºC from 1971–2006 ($F_{1,34}$=11.13, P=0.002); and in the last thirty years (1976–2006) the daily maximum temperature increased by 1.28ºC ($F_{1,29}$=9.97, P=0.003). Accordingly, the length of the vegetation period increased by 25.9±9.0 days from 1971–2006 ($F_{1,32}$=8.21, P=0.007). Whereas the beginning of the vegetation period did not significantly change from 1959–2006 ($F_{1,44}$ =1.54, P>0.2), the end of the vegetation period from 1971–2006 shifted forward by 15.41 ± 5.1 days ($F_{1,34}$=9.16, P= 0.005).

Biomass

Aboveground biomass of vascular plants was harvested within the 1 x 2 m plots in randomly chosen subplots of 18.5 x 18.5 cm. In the first survey, aboveground biomass was sampled in four plots per site and in three 18.5 x 18.5 cm subplots within each plot. In the second survey, biomass was harvested in all five plots per site but in only one subplot within each plot. In both surveys, biomass was harvested at peak standing crop. Biomass samples were dried (70º C, 48h), weighed and extrapolated to g per m^2 (see Bergamini *et al.*, 2009).

Statistical analysis

Data were analyzed using the statistical software R (Version 2.6.2 for Windows; R development core team, 2007) using mixed-model analysis of variance (ANOVA). The sequential analyses included main effects of management, altitude (effective altitude rather than altitudinal class was used as explanatory variable) and survey date (1995 vs. 2005/06) and their interactions (Tables 2, 3). Altitude was defined as the altitude of the central plot at each site in m a.s.l. Site and plot were considered random effects. It should be noted that different, but nearby plots were used in the two surveys (see Bergamini *et al.*, 2009) and thus the plot term corresponded to a plot x survey date interaction. The fixed effects of management and altitude and their interactions were tested against the random effects of sites. Interactions between these factors and survey date were tested against the site x survey date interaction (random). For the analysis of soil abiotic condition and biomass, the random effects of site and of the site x survey date interaction were tested against the residual variation among all plots (Tables 2, 3; see also Bergamini *et al.*, 2009).

The number of colonizing species (CS), extinct species (ES), and the extinction (ER) and colonization rates (CR) were calculated for each group vs. all other species over the 10-year period (Table 1). Species were counted as colonizing if they were absent in the first survey (1995) and present in the second (2005/06); if species were present in the first survey but absent in the second, they were considered locally extinct for the purpose of this analysis. Colonization, extinction and turnover rates were based on absence/presence data and calculated as CR = 100(CS*2)/ (G95+G05/06); ER = 100(ES*2)/ (G95+G05/06), and as TR = 100(ER+CR)/ (G95+G05/06) where G denotes the total number of species per group that was considered (Nilsson & Nilsson, 1982; Joshi *et al.*, 2006). To test whether the colonization and extinction rate differed between each group vs. other species and whether this difference was affected by altitude or management, we performed sequential ANOVAs similar to those described above (see Table 2), but with the additional terms “group vs.

other", "group vs. other x altitude" and "group vs. other x management", all fitted after site. These effects were tested against the final random term "group vs. other x site".

To overcome the bias problem in soil analyses mentioned above, we tested whether the changes in soil variables per site over the 10-year period significantly correlated with extinction or colonization rate per site and compared these correlations between each group vs. other species (ANOVAs with extinction or colonization rate per site as dependent variable and change in soil variable, "group vs. other" and interaction as explanatory terms).

To compare species changes within each ecological group, we used t-tests to analyze whether there were more colonization than extinction events in any group or vice versa.

Results

In total, we detected 229 vascular plant species belonging to 50 different plant families in our plots (see Table S1). Of these 229 species, 10 were tree species and the majority of the non-woody species were perennials (only 5 species were short-lived annuals). Nearly two-thirds of the non-woody species (65.3%; Table S1) were clonal. Averaged across all sites, species density (richness /10 m^2) of all vascular plants increased from 60.44 ± 1.57 in 1995 to 63.22 ± 1.66 in 2005/06 (Table 2). Management, but not altitude, had a significant influence on vascular-plant species density with a 12% lower species density on average in grazed compared with mown fens (Table 2). This management effect on species density did not change over time (Table 2).

Biotic and abiotic environmental changes

In the second survey, aboveground biomass of vascular plants was almost 30% higher than in the first survey (increase from 254 ± 9.9 to 329 ± 10.4 g m^{-2} over the 10-year study period; Table 3; see also Bergamini *et al.* 2009). This increase was strongest at higher altitudes in grazed fens (Table 3).

Averaged over all sites, the soil concentrations of NO_3^- and PO_4^{3-} did not change from 1995–2005/06, but total soil nitrogen and carbon decreased significantly from 1.61% ± 0.83% to 1.44% ± 0.77% and from 24.12% ± 0.22% to 21.1% ± 0.19%, respectively, and soil pH decreased from 6.12% ± 0.05% to 6.00% ± 0.05% (Table 3; see bias problem mentioned in the Materials and Methods section). Furthermore, within-site changes in soil

NO_3^- and PO_4^{3-} over this time period were not significantly correlated with colonization or extinction rates of any ecological group (all $P>0.14$). The colonization rate of any group was as well never significantly correlated with within-site changes in total soil nitrogen, carbon and pH. However, the extinction rate of species with low habitat-specificity decreased with an within-site increase in total soil nitrogen content ($F_{1,30}=4.29$, $P<0.05$; Fig. 3a) and the extinction rate of acid soil indicators was positively correlated with the within-site changes in soil pH ($F_{1,30}=5.10$, $P=0.03$; Fig. 3b).

Colonization, extinction and species turnover

Colonization, extinction and turnover rates are analyzed in Table 4. The number of local colonization events as well as the colonization rate was significantly positive (Table 4) and colonization rate marginally decreased with increasing altitude (Table 4; Fig. 4). Most of our ecological groups defined in Table 1 had a significantly different colonization rate than other species not belonging to their group (Fig. 4; Table 4). In particular, warm-temperature as well as rich-soil species and shade indicators had a substantially higher colonization rate than other species (Fig. 4). The colonization rate of shade indicators was twice as high as that of others across all altitudinal levels (59.6% ± 5.9% vs. 25.9% ± 1.3%). Early-flowering species had marginally higher colonization rates than other species ($F_{1,31}=3.60$, $P=0.067$) and especially colonized grazed fens at low altitude (management x altitude interaction: $F_{1,31}=4.08$, $P=0.05$) Whereas species with low habitat specificity had an overall high colonization rate in grazed fens, but in mown sites especially colonized low-altitude fens (management x altitude interaction: $F_{1,31}=5.02$, $P=0.03$). The colonization rate of acidic soil indicators tended to decrease with increasing altitude ($F_{1,31}=2.88$, $P=0.09$; Fig. 4). In contrast to all these previous groups, fen specialists, peat indicators and late-flowering species had a lower colonization rate than other species not belonging to their groups (Fig. 4).

Similar to colonization, the number of local extinction events and extinction rate were significantly positive (Table 4). The extinction rate was generally not affected by altitude or management (Table 4), except for specific ecological groups. For acidic-soil indicators the extinction rate was particularly high at low altitudes (Fig. 5). In contrast, extinction rates increased with altitude for rich soil species and shade indicators (Fig. 5).

Late-flowering species had lower (Fig. 5), whereas warm-temperature species had higher extinction rates than others.

Comparing colonization and extinction rates (Fig. 6), the colonization rates of warm-temperature species, of early-flowering and rich-soil species, of species with low habitat specificity and shade indicators were significantly higher than their extinction rates. Of the different groups tested only the colonization rate of fen specialists was lower than their extinction rate.

Discussion

Despite legal protection and no obvious change in the traditional management system in the montane fen meadows investigated, we observed a significant decline in species density of fen specialists but a concomitant increase in species density of other groups of vascular plants from 1995–2005/06. The increase in overall species density of vascular plants was not only significant at the site level, but was also observable at a smaller spatial scale of 2 m^2 (Bergamini *et al.*, 2009).

Within the last 30–50 years, daily mean, minimum and maximum temperatures increased significantly in the study region. The mean annual precipitation, however, remained relatively constant over this time period (Bergamini *et al.*, 2009). In a spatially explicit model, Kienast *et al.* (1998) predicted that plant species richness in Switzerland might increase especially in mountainous areas under a scenario of climate warming and constant precipitation. Such an increase in the species richness of vascular plans has already been observed from 1994–2004 at high-altitude sites in the Austrian Alps (Pauli *et al.*, 2007). In these high mountain ecosystems, the increase in floristic diversity has been attributed to recent climate warming, which has been twice as high in the Alps than the global average (Pauli *et al.*, 2007). An upwards migration of plant species with the highest increase in species richness in the transitional zone between alpine and nival ecosystems has also been observed during the past 50 years in the Rhaetian Alps in Northern Italy (Parolo & Rossi, 2008). In our pre-Alpine fen meadows, the colonization rate of climate-change indicators (early-flowering species and warm-temperature species) exceeded their extinction rate significantly (see Fig. 6). Late-flowering species (seed riskers) that might benefit from the observed longer vegetation period, however, had lower colonization (and extinction) rates. These late-flowering species might have been prevented from thriving under the potentially more favorable climatic conditions by the mowing treatment in late summer. The only group of species, which had a higher extinction than colonization rate, was fen specialists (see Fig. 6).

Multi-factorial causes of changes in species density of vascular plants

During the 10-year observation period, our fen sites increased in productivity and therefore presumably shadiness increased as well. The increased productivity may have been caused by air-borne nitrogen deposition as well as by lowered ground-water tables in these wetland ecosystems (Bergamini *et al.*, 2009) and possibly also by increased species density, higher air temperature and a longer vegetation period. A greater resource investment in vegetative growth as a response to artificial warming by 1.5°C during 4 years has been observed by Arft *et al.* (1999) in low-arctic vegetation. The higher productivity in our fens might in part explain the lower total soil nitrogen measured in the 2005/06 than in the 1995 survey (in addition to the bias caused by removing fine roots more completely in the second survey): it is well known that in biodiversity experiments a higher primary productivity caused by higher species richness leads to lower soil nitrogen levels (Balvanera *et al.,* 2006). The high colonization rate of rich soil species and the low colonization rates of peat indicators (see Fig. 4) also suggest a change in soil conditions away from the typical fen soil over the short observation period from 1995–2005/06. Desiccation of wetland soils leads to higher soil respiration and increased peat decomposition (Rydin & Jeglum, 2006). Increased nutrient spill-over from adjacent agricultural areas and increased airborne N-deposition as well as a disturbed hydrology has also been observed in a recent quality assessment of Swiss wetland ecosystems comparing protected fen and mire ecosystems (Klaus, 2007).

Fen specialists seem to be rather inflexible under environmental change (Erschbamer, 2007), whereas species with a low habitat-specificity presumably can react more plastically to such change. Thus, the latter indeed had higher colonization than extinction rates in our fen meadows. Putatively pre-adapted species (i.e. warm-temperature as well as rich-soil species and shade indicators) had the highest colonization rates during the 10-year observation period and obviously were not negatively affected by the observed increase in temperature and other drivers such as habitat fragmentation and isolation (Lienert *et al.*, 2002; Fakheran *et al.*; personal data) as well as nutrient spill-over from intensively used adjacent areas and increased atmospheric nitrogen deposition (Klötzli, 1986; Pauli *et al.*, 2002). The most successful colonizers during the observation period were thermophilous grass species with low habitat specificity, such as *Festuca rubra* and *Dactylis glomerata*, or generalist warm-temperature herbs, such as *Leucanthemum vulgare*, which colonized between 17–23% of the sites and either never got extinct (*F. rubra*) or only disappeared at 5.7% of the sites (*D. glomerata, L. vulgaris*). Because changes in soil nutrients were neither significantly related to the colonization nor to the extinction rate of any putative climate change indicator, we conclude that the observed increase in species densities of the above-mentioned groups of was most likely caused by climate warming and other possibly more subtle environmental changes. An increased colonization indicating a latitudinal shift of thermophilious species was also observed during the final decades of the 20^{th} century in the Netherlands (Tamis *et al.*, 2005) and a comparison of bryophyte species records in Switzerland from 1880–2005 showed an upward shift in altitudinal limits, which was mainly driven by cryophylous species (Bergamini *et al.*, 2009).

Altitudinal gradients

The main shift in vegetation composition occurred at low-altitude sites, which overall were affected by higher colonization rates than were high altitude sites (Table 4). Indicators of soil-quality change (rich soil species) and of differences in community productivity (shade indicators) went less often extinct at low than at high altitude sites. Clear altitudinal gradients were observed in mown fens with e.g. an increase in colonization of low habitat-specificity species and an increase in extinction of peat indicators with decreasing altitude. Altitudinal patterns in grazed fens, however, were less often detected, probably because of masking effects of land-use peculiarities (Körner, 2007), e.g. different stocking rates and average cattle weight at different altitudes.

Our findings show that specific ecological groups of species in the studied calcareous fen meadows respond differentially, but predictably (Bazzaz, 1996) to multi-factorial environmental change: warm-temperature and generalist vascular plant species with low habitat specificity often colonized new sites, particularly at low altitudes, whereas fen specialists did not adapt and went extinct at a higher rate over the observation period from 1995–2005/06. We suggest that the observed increase in temperature in the study region, leading to an elongated vegetation period, is one of the main drivers of these species’ range shifts.

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Table 1 Classification of the 229 recorded vascular plant species into mutually non-exclusive groups based on phenological and ecological characteristics putatively influenced by climate and other drivers of environmental change such as change soil variables and plant community aboveground biomass production.

Characterization	Group	Reference for classification	Description	Group size
1) general habitat change	Fen specialists	BUWAL 1990	Species characteristic of the *Caricetalia davallianae* vegetation type vs. others	24 species
	Species with low habitat-specificity	Fischer and Stöcklin 1997, Joshi et al. 2006	Ubiquitous species vs. species that occur only in specific habitat types	51 species
2) climate change	Early-flowering species	Lauber & Wagner 1996	Species that start flowering early, (March–May) vs. others	42 species
	Late-flowering species	Lauber & Wagner 1996	Species that start flowering in July–October vs. plants that flower before	35 species
	Warm-temperature species	Landolt 1977	Warm temperature, i.e. colline and Southern European species vs. alpine, subalpine, montane species	37 species
3) soil quality change	Acidic-soil indicators	Landolt 1977	Acid soil indicators (pH 3–5.5) vs. others	40 species
	Changing soil-humidity indicators	Landolt 1977	Plants chiefly occuring on soils with varying humidity vs. others	132 species
	Rich-soil species	Landolt 1977	Species chiefly occuring on medium to rich soils vs. poor soil indicators	114 species
	Peat indicators	Landolt 1977	Peat soil indicators avoiding mineral soils vs. others	31 species
4) community productivity change	Light indicators	Landolt 1977	Plants growing in full light vs. half-shade–shade plants	124 species
	Shade indicators	Landolt 1977	Shade indicators occuring often under 10% relative strength of illumination vs. others	17 species

Table 2 Effects of management (grazed vs. mown), altitude and survey date (1995 vs. 2005/2006) on cumulative species density of vascular plants per 10 m^2 (five plots of 1 x 2 m). *: $P \leq 0.05$, **: $P \leq 0.01$, ***: $P \leq 0.001$, ns: not significant.

Source of variation	df	*F*	*P*	SS (%)
Management (M)	1	8.26	**	17.22
Altitude (A)	1	1.20	ns	2.51
M x A	1	0.87	ns	1.81
Site	31	5.83	***	64.65
Survey date (D)	1	6.41	*	2.28
M x D	1	2.55	ns	0.91
A x D	1	0.95	ns	0.34
M x A x D	1	0.01	ns	0.003
Residuals	31			11.07

Table 3 Effects of management (grazed vs. mown), altitude and survey date (1995 vs. 2005/06) on above-ground community biomass per m^2 of vascular plants and five soil variables. (*): P<0.1, *: P≤0.05, **: P≤0.01, ***: P≤0.001.

Source of variation	**ln Biomass**			**NO_3^-,**			**PO_4^{3-}**		**Total N**		**Total C**		**pH**		
	df	SS (%)	*F*	df	SS (%)	*F*	SS (%)	*F*	SS (%)	*F*	SS (%)	*F*	df	SS (%)	*F*
Management (M)	1	0.62	0.94	1	0.12	0.17	2.49	3.59	2.06	1.68	2.18	1.80	1	0.25	0.16
Altitude (A)	1	5.82	**8.83****	1	0.06	0.08	0.10	0.14	0.25	0.20	0.17	0.14	1	0.25	0.16
M x A	1	2.12	3.21 (*)	1	0.06	0.09	0.49	0.71	0.05	0.04	0.01	0.01	1	0.28	0.18
Site	33	21.76	**3.16*****	33	23.67	**2.14****	22.89	**1.72***	40.39	**4.70*****	40.04	**4.44*****	33	51.19	**9.16*****
Survey date (D)	1	8.81	**42.21*****	1	0.51	1.52	0.68	1.68	1.31	**5.05***	1.80	**6.59***	1	1.18	**6.98****
M x D	1	0.08	0.40	1	0.04	0.12	0.01	0.02	0.31	1.18	0.11	0.43	1	0.00	0.02
A x D	1	0.66	3.18 (*)	1	0.85	2.53	0.00	0.00	0.58	2.22	0.14	0.53	1	0.00	0.00
M x A x D	1	0.67	3.22 (*)	1	0.44	1.31	0.11	0.27	0.02	0.09	0.00	0.01	1	0.00	0.00
S x D	33	9.55	1.39 (*)	33	17.96	**1.62***	5.33	0.40	11.32	1.32	9.63	1.07	33	7.06	1.26
Residuals	239	49.90		168	56.30		67.90		43.71		45.90		235	39.78	

Table 4 Difference of overall mean of extinction, colonization and turnover rate from zero and effects of management (grazed vs. mown), altitude and their interaction on the number of colonization and extinction events and colonization (CR), extinction (ER) and turnover rates (TR) per site. (*): *P*=0.05, *: *P*≤0.05, ***: *P*≤0.001.

Source of variation	df	**# colonizations**		**# extinctions**		**CR (%)**		**ER (%)**		**TR (%)**	
		SS	*F*	SS	*F*	SS	*F*	SS	*F*	SS	F
Mean	1	8928.0	384.1***	5993.3	286.2***	23578.7	416.0***	15967.2	291.2***	19588.1	823.5***
Altitude (A)	1	50.7	2.2	0.0	0.0	224.9	4.0 (*)	1.1	0.0	64.3	2.7
Management (M)	1	0.2	0.0	6.8	0.3	138.5	2.4	148.9	2.7	143.7	6*
A x M	1	35.4	1.5	28.8	1.4	33.0	0.6	74.1	1.3	51.6	2.2
Residuals	31	720.6		649.2		1756.9		1699.8		737.4	

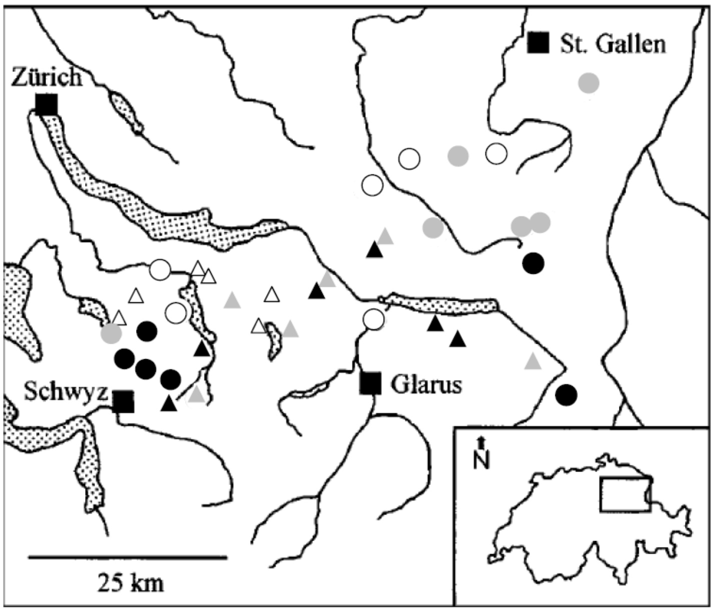

Fig. 1 Distribution of 36 fen sites in central and north-eastern Switzerland. The sites differed in management regimes and were classified into three altitudinal classes (class I: 800–1000; class II: >1000–1200; class III: >1200–1400 m a.s.l.). Mown-class I: ○, Mown-class II: ●, Mown-class III: ●, Grazed-class I: △, Grazed-class II: ▲, Grazed-class III: ▲ (modified after Pauli *et al.* 2002).

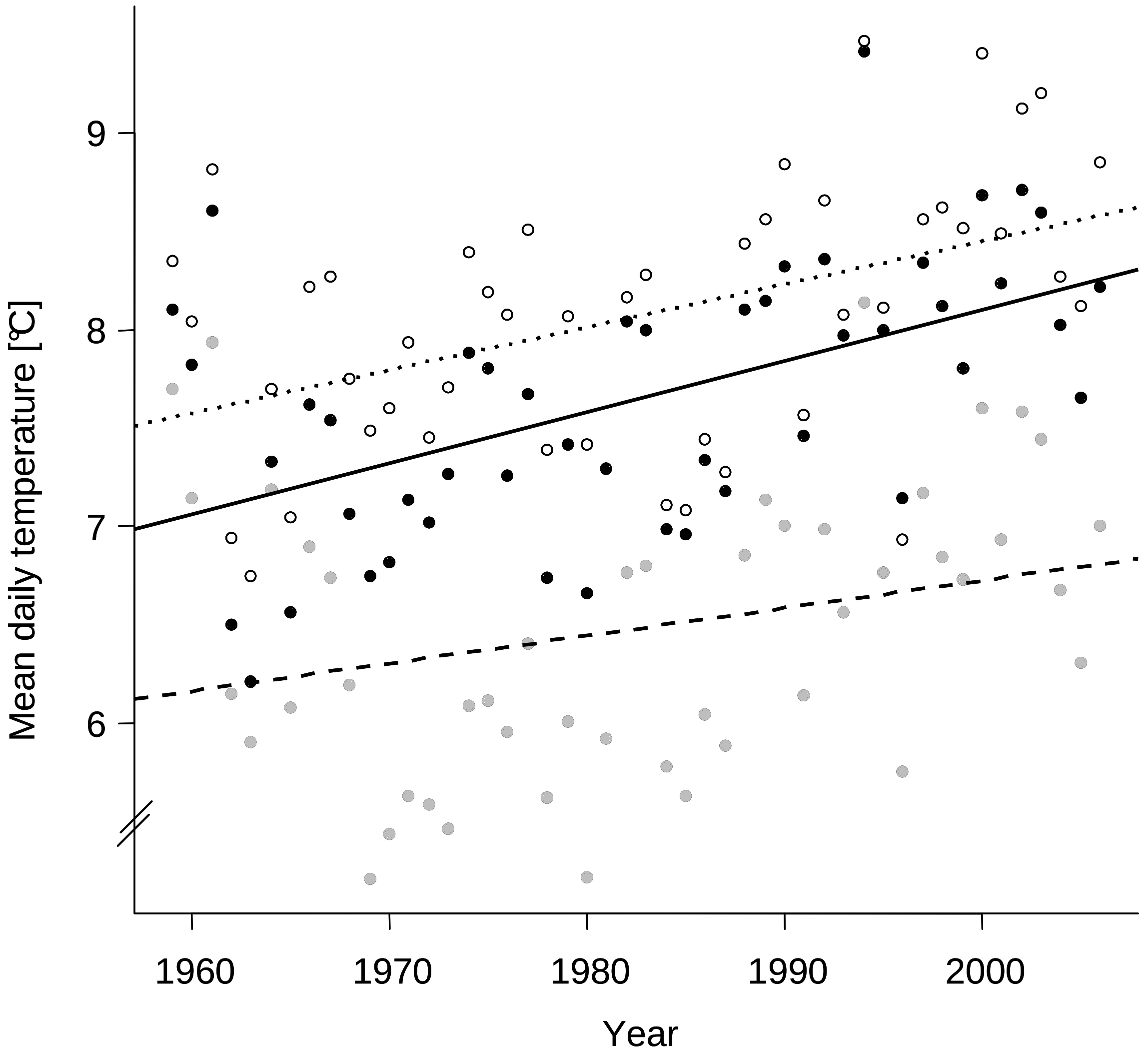

Fig. 2 Mean daily temperatures [°C] measured at three climate stations within the study region from 1959–2006. Dotted line, white points: St. Gallen, 779 m a.s.l.; solid line, black points: Ebnat-Kappel, 623 m a.s.l.; dashed line, grey points: Einsiedeln, 910 m a.s.l.

Fig. 3a

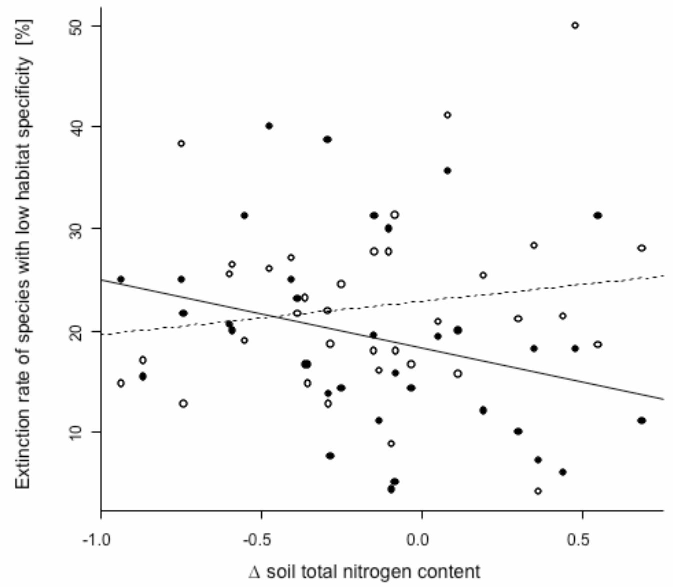

Fig 3b

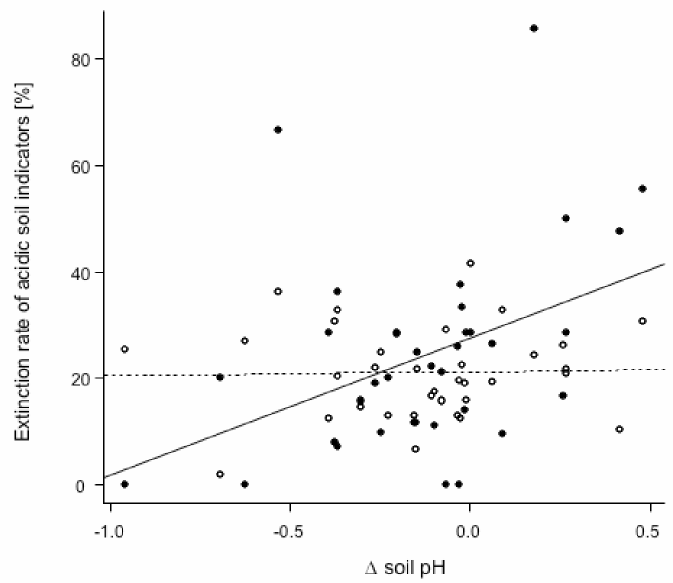

Fig. 3 a) Effect of within-site change from 1995–2005/06 in total soil nitrogen content on the extinction rate of species with low habitat-specificity (solid line and circles) vs. others (dashed line, open circles) ($F_{1,30}$=4.29, P<0.05) and **b)** effect of within-site soil pH changes on extinction rate of acidic-soil indicators (solid line and circles) vs. others (dashed line, open circles; $F_{1,30}$=5.10, P=0.03).

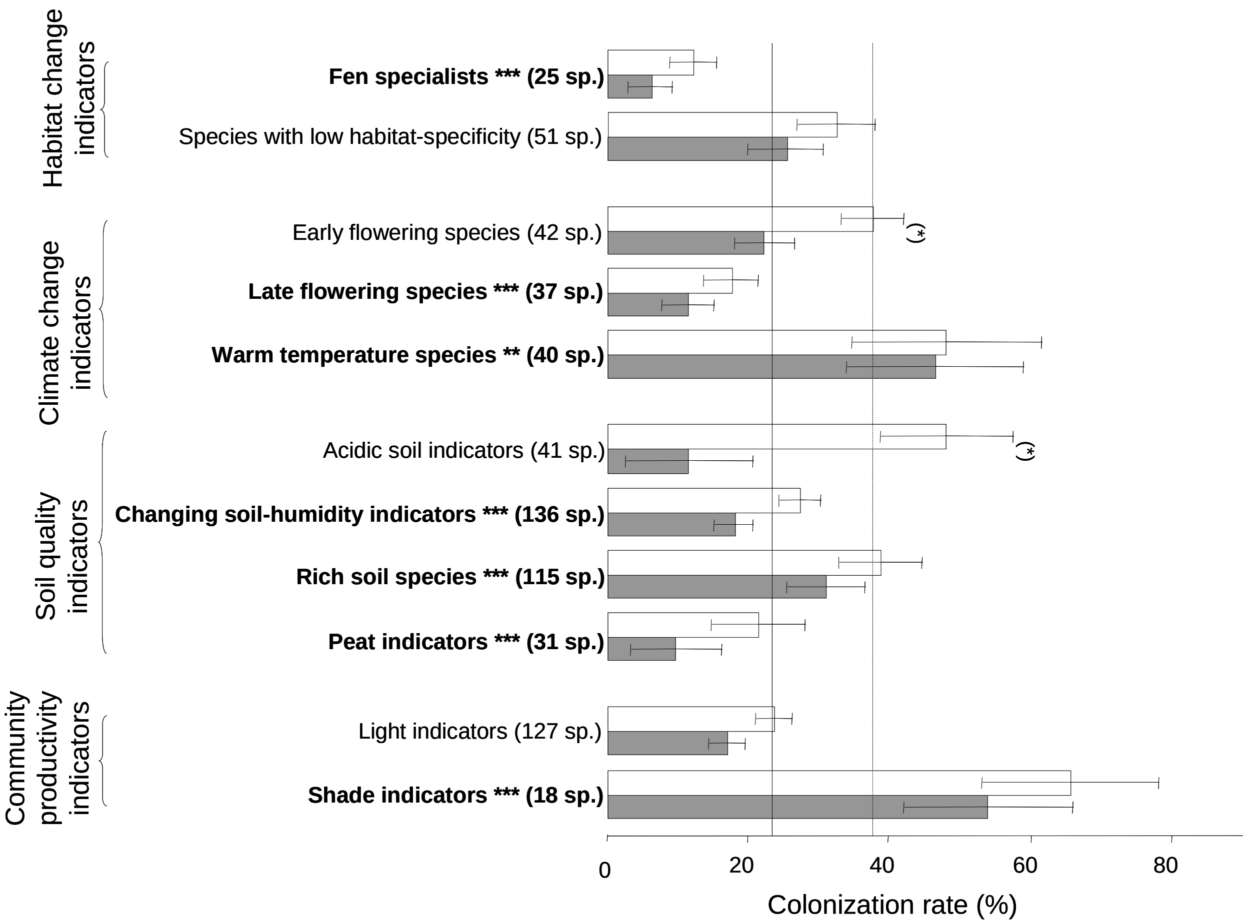

Fig. 4 Colonization rate for each group at the lowest (800 m a.s.l; white bars) and the highest altitude (1400 m a.s.l.; grey bars; values fitted by regression analysis). Numbers in brackets after group names indicate the number of species in each ecological group. Bold formatted group names and asterisks indicate that the colonization rate was significantly different between species in the respective group vs. other species. The stars on the bars indicate whether the interaction effect of altitude x group was significant: (*): $P<0.1$. The horizontal lines show the overall mean of fitted values at 800 m a.s.l. (dashed line) and 1400 m a.s.l. (solid line), respectively. The overall colonization rate was higher at low than at high altitudes ($F_{1,31}=4.0$, $P=0.05$).

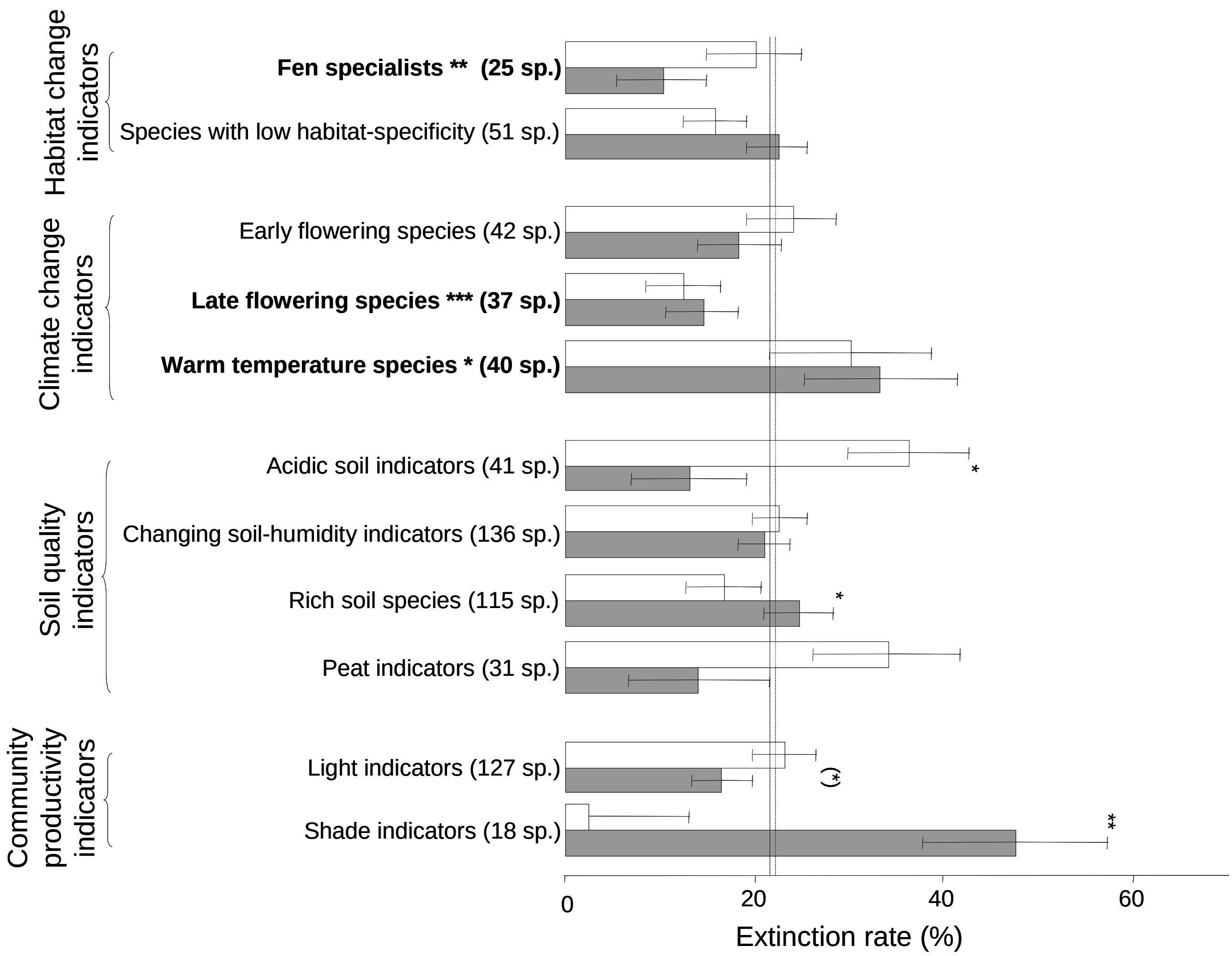

Fig. 5 Extinction rate for each group at the lowest (800 m a.s.l; white bars) and the highest altitude (1400 m a.s.l.; grey bars; values fitted by regression analysis). Numbers in brackets after group names give the number of species in each ecological group. Bold formatted group names and asterisks indicate that the extinction rate was significantly different between species in the respective group vs. other species: (*): $P<0.1$, *: $P \leq 0.05$, **: $P \leq 0.01$. The stars on the bars indicate whether the effect of altitude x group was significant. The horizontal lines show the overall mean of fitted values at 800 m a.s.l. (dashed line) and 1400 m a.s.l. (solid line), respectively.

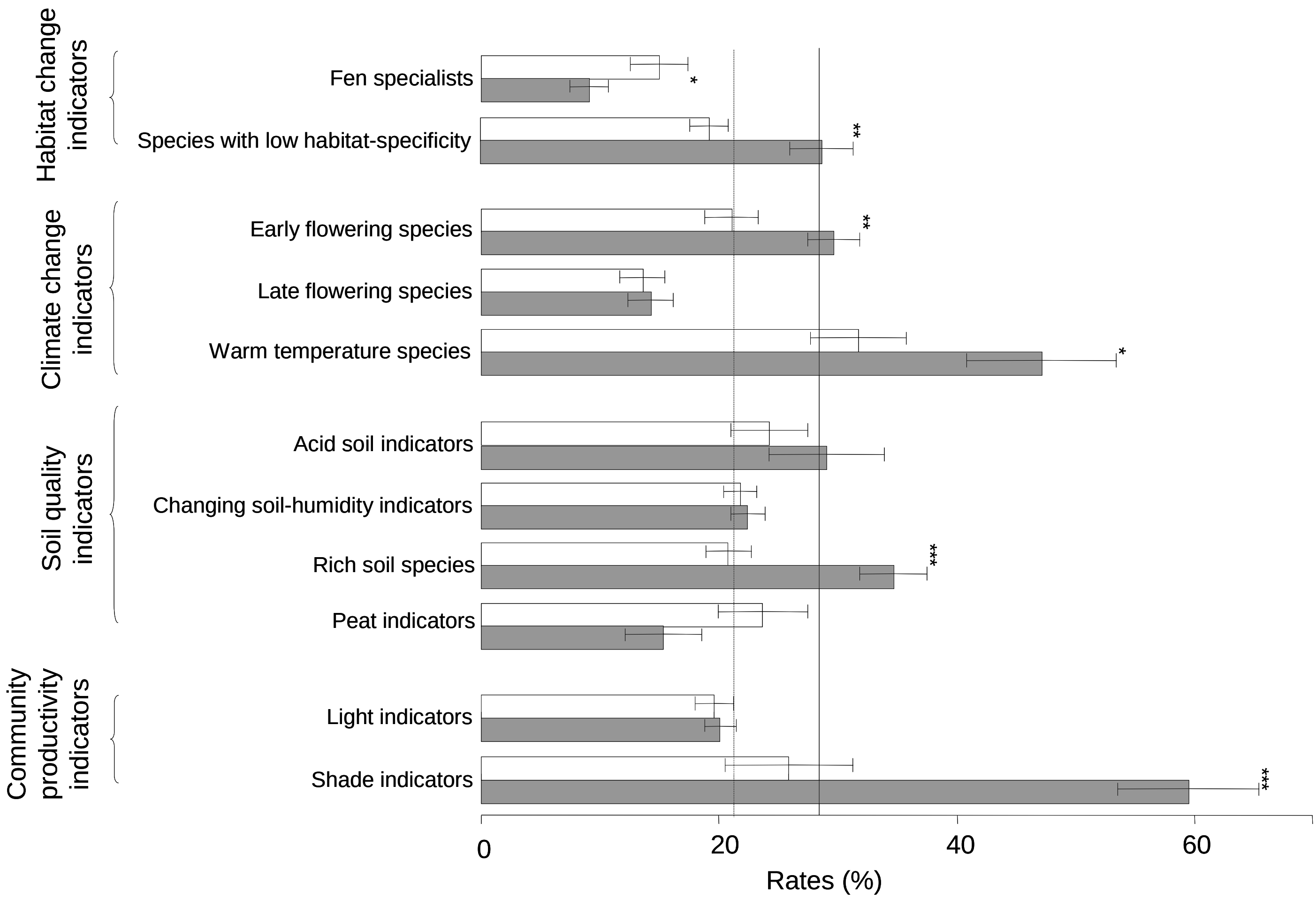

Figure 6 Group-wise differences between extinction (white bars) and colonization rates (grey bars) compared by t tests: *: $P \leq 0.05$, **: $P \leq 0.01$, ***: $P \leq 0.001$. The horizontal lines show the overall mean of extinction rates (dashed line) and colonization rates (solid line), respectively.

3

Loss of habitat specialists despite conservation management in fen remnants 1995–2006

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Abstract

Many ecosystems of high conservation value have been shaped by human impacts over centuries. Today, traditional management of semi-natural habitats is a common conservation measure in Europe. However, despite traditional management, habitat remnants may still loose specialist species due to surrounding land-use change or atmospheric nitrogen deposition. To detect trends in species density (2-m^2 plot scale) and habitat quality in calcareous fens in the pre-Alps of Switzerland, we surveyed 36 traditionally managed fens in 1995/97 and again in 2005/06 (five plots per fen). The fens occurred at three altitudinal levels (800–1000, 1000–1200, 1200–1400 m a.s.l.) and were either extensively grazed or mown once a year. Despite these traditional management regimes, species density of fen specialists and of all bryophytes decreased during this decade (vascular plant specialists: –9.4%, bryophyte specialists: –14.9%, all bryophytes: –5.7%). Management had no effect on the number of Red-List species and habitat specialists of vascular plants per plot. However, bryophyte species density was more strongly reduced in grazed fens. Species density of vascular plant generalists increased between the two surveys (+8.2%) but not of bryophytes. Among vascular plants, Red-List species decreased from 1.01 to 0.78 species per plot. Furthermore, between the two surveys aboveground plant biomass, mean plant-community indicator values for nutrients and species density of nutrient indicators increased, whereas mean plant indicator values for soil moisture, light and peat, and species density for peat indicators, decreased. We attribute these changes and the loss of specialist species over the past decade mainly to land-use change in the surrounding area and to nutrient inputs. Thus, despite traditional management, calcareous fens in the pre-Alps suffer from ongoing habitat deterioration and endangered plant species remain threatened. For their long-term protection, we suggest to reduce nutrient inputs and, where necessary, to restore hydrology and adjust grazing management.

Key words*:* bryophytes, calcareous fen, grazing, indicator value, Red-List species, habitat specialist, vascular plants

Introduction

Europe has a long history of human modification of its ecosystems (Thomas, 1956). As a consequence, wilderness areas in Europe are rare and many European ecosystems of high conservation value have been shaped over the centuries by human impact. Hence, in contrast to other world regions, nature conservation in Europe strongly relies on the continuation of traditional management methods (Sutherland, 2002). Despite traditional management, however, conservation values still may decrease because of various direct and indirect threats to biodiversity such as nitrogen deposition or climate change. It is thus important to monitor whether conservation values within traditionally managed sites are maintained or if there is an ongoing deterioration despite protection efforts.

In this study, we focus on calcareous fens in the Swiss pre-Alps. Calcareous fens belong to the most species-rich grasslands in Europe and contain many habitat specialists and endangered species (Grünig, 1994; Ellenberg, 1996; van Diggelen et al., 2006). In the European Union Habitats Directive, they are considered a priority habitat for conservation. In Switzerland, all fens of national importance are protected since 1987 by the federal constitution and for most sites management contracts exist to ensure the traditional management (Grünig, 1994; Klaus, 2007).

Most calcareous fens in Switzerland are semi-natural, nutrient-poor habitats, which are not artificially fertilized and either mown late in the year or extensively grazed. Before legal protection, many fens have been destroyed by drainage and fertilization (BUWAL, 1990). Thus, the once large and continuous fen landscape in the Swiss pre-Alps has been converted into an archipelago of fen remnants. As a consequence and despite of traditional management, specialist species in fen remnants may suffer from isolation and altered abiotic conditions associated with edge effects (Lienert et al., 2002; Hooftman et al., 2003; Galeuchet et al., 2005; Bossuyt, 2007), from continuing land-use change in the surroundings (e.g. altered hydrological conditions: Fojt and Harding, 1995; Bollens et al., 2001), from nutrient spill-over from more intensively used areas as well as from atmospheric nitrogen deposition (Klötzli, 1986; Bergamini and Pauli, 2001; Pauli et al., 2002). In addition, they may be affected by global warming and associated climate change (Weltzin et al., 2003, H. Moradi et al., unpublished data). It is conceivable that all these factors affect habitat specialists negatively, whereas generalists may benefit (Fischer and Stöcklin, 1997; Pauli et al., 2002; Travis, 2003; Bennie et al., 2006). In fens, these latter species are often more productive and better adapted to disturbed sites than the specialists and thus put additional competitive pressure on the already disadvantaged specialists (e.g. Pauli et al., 2002).

The management of the protected fens, in combination with the factors mentioned above, may also affect the plant-species composition of the studied fens. We have previously shown that some fen taxa benefit from grazing and others from mowing (vascular plants: Peintinger, 1999; butterflies and grasshoppers: Wettstein and Schmid, 1999; bryophytes: Bergamini et al., 2001b). On the landscape level, a mixture of both management types was therefore recommended for the long-term protection of fen taxa (Peintinger, 1999; Wettstein and Schmid, 1999; Bergamini et al., 2001b). Given current threats such as eutrophication or climate change, however, favourability of management types may change.

In this paper, we concentrate on vascular plants and bryophytes, which are important components of calcareous fens in terms of species richness and biomass (Bergamini et al., 2001a; Peintinger et al., 2003). The two groups differ considerably in morphological, physiological, and ecological traits. Bryophytes are poikilohydric, and water and nutrients are absorbed over the whole surface (Schofield, 1985). Bryophytes may thus react differently to environmental changes than vascular plants and may indicate such changes earlier.

The aim of this paper was to study recent trends in species density of both vascular plants and bryophytes, and to identify their possible underlying environmental causes. We re-visited 36 calcareous fens, which we already studied in the mid-nineties of the last century (Peintinger, 1999; Bergamini et al., 2001b; Peintinger et al., 2003) and assessed species density at 180 plots in total as well as plant functional characteristics based on ecological indicator values (Landolt, 1977). Given the substantial governmental subsidies paid to the farmers for traditional management of fens, we particularly assessed 1) whether diversity of species of high conservation concern and habitat quality was maintained in the traditionally managed areas, and 2) whether species turnover over the 10-y time span and changes in habitat quality differed between the two traditional management regimes grazing and mowing.

Materials and methods

Study sites

The study area covered approximately 3500 km^2 in the pre-Alps in the north-eastern part of Switzerland (for a map of the study area see Bergamini et al., 2001b). Within this area, more than 300 fens of at least 1 ha exist (BUWAL, 1990). In 1995, we randomly selected 36 fens with the restriction that they contained vegetation of the *Caricion davallianae* type (Ellenberg, 1996). The fens chosen were all traditionally managed, but differed in the type of management (mown vs. grazed) and altitude (800–1000, >1000–1200, >1200–1400 m a.s.l.) according to a balanced factorial design. Furthermore, the selection was done in a way to avoid a confounding of site area with the above classification factors (Bergamini et al., 2001b).

Vegetation monitoring

In each fen, five plots of 1 x 2 m were sampled for bryophytes and vascular plants (in total 180 plots distributed over the 36 fens). The first survey of vascular plants was conducted in July and August 1995 (Pauli, 1998; Peintinger, 1999), the first survey of bryophytes between May and July 1997 (Bergamini et al., 2001b). Because in 1995 plots were not marked as permanent, plot locations for bryophytes and vascular plants were not identical in the first survey. However, for both groups the same random procedure was applied to select plot locations within fens: each fen was divided in 4 sectors and each sector was again split into 4 subsectors. Within each sector, one subsector was randomly chosen and one plot was then randomly located within that subsector. One additional plot was placed in the center of each fen. To avoid large differences in environmental conditions, plots that did not contain *Carex davalliana* (a frequent, small, tussock-forming sedge characteristic of the Caricion davallianae alliance, Ellenberg, 1996), were replaced by a new randomly selected, plot of the same subsector containing this particular species. A second survey of all 36 sites took place in July and August 2005 (24 sites) and July 2006 (12 sites). Shape and size of plots were identical to the first survey. At the second census, vascular plants and bryophytes were sampled on the same plots.

In both surveys, a complete species list was compiled for both vascular plants and bryophytes. Difficult-to-identify vascular plant species and all bryophyte species were collected for later determination. Nomenclature for vascular plants follows Lauber &

Wagner (2001), for mosses Hill et al. (2006) and for liverworts Grolle & Long (2000). Vascular plants were grouped into four taxonomic-functional groups: sedges (Cyperaceae and Juncaceae), grasses (Poaceae), legumes (Fabaceae), and non-legume herbs (all other species, including tree seedlings). Bryophytes were assigned to the two main phylogenetic clades, liverworts (Hepaticae) and mosses (Musci). We considered all nationwide 'critically endangered', 'endangered', 'vulnerable', and 'nearly threatened' species as 'Red-List species'. Red-List status for vascular plants was based on Moser et al. (2002) and for bryophytes on Schnyder et al. (2004). Red-List species included vascular plants such as *Herminium monorchis*, *Gentiana pneumonanthe*, *Scorzonera humilis* or *Swertia perennis* and bryophytes such as *Hamatocaulis vernicosus*, *Meesia triquetra* or *Cinclidium stygium*.

For the designation of vascular plants with high habitat specificity (habitat specialists), we used the 25 species listed as characteristic of the *Caricetalia davallianae* alliance in the appendix to the Swiss fen inventory (BUWAL, 1990, see Table 1). Because no similar list exists for bryophytes, we treated all bryophytes, which are typical for 'calcareous fens', 'extremely rich fens' and 'rich fens' according to Hajek et al. (2006) as habitat specialists. We found 16 such specialist bryophytes. Based on our own studies (A. Bergamini, unpublished data), we removed five species from this group because they also occur outside *Caricion davallianae* fens (*Calliergonella cuspidata, Chiloscyphus pallescens* [incl. *C. polyanthos*], *Aulacomnium palustre, Palustriella commutata, Sphagnum teres*). Based on further reference works (in particular Braun, 1968; Nebel and Philippi, 2000-2005; Berg and Dengler, 2005) and our own experience, we added eight species to the group of bryophyte specialists (*Brachythecium mildeanum, Brachythecium turgidum, Pseudocalliergon trifarium, Palustriella decipiens, Palustriella falcata, Meesia triquetra, Sphagnum contortum, Sphagnum warnstorfii*). Finally, the list contained 19 bryophyte species, which we considered habitat specialists (Table 1). All species not classified as habitat specialists were regarded as generalists.

We further used indicator values after Landolt (1977) for vascular plants occurring in Switzerland to assign species to ecological groups. Landolt's indicator values follow an ordinal scale and range from 1–5 (low numbers represent low, high numbers high resource requirements). Indicator values for vascular plants have been widely used in vegetation ecology (Diekmann, 2003) and proven to be an important tool for analyzing environmental causes of changes in vascular plant species richness (Stehlik et al., 2007).

We used the following groups: indicators of wet soils (species with Landolt humidity values ≥ 4), light indicators (species with Landolt light values ≥ 4), indicators of nutrient-rich soils (species with Landolt nutrient values ≥ 3), indicators of acidic soils (species with Landolt soil-reaction values ≤ 2), peat indicators (species with Landolt organic content values = 5). Additionally, we calculated mean indicator values for soil moisture, light availability, soil nutrients, soil acidity and soil organic content based on presence/absence data of vascular plants for each plot in both surveys.

Aboveground biomass of vascular plants was harvested within the 1 x 2 m plots in randomly chosen subplots of 18.5 x 18.5 cm^2 by clipping the plants just above the ground. In the first survey, aboveground biomass was sampled in four of the vascular plant plots per site and in three subplots within each plot. In the second survey, biomass was harvested in five plots and in one subplot within each plot. In both surveys, biomass was harvested at peak standing crop. Biomass samples were dried (70ºC, 48 h) and weighed.

In the first survey, we collected soil samples from both the vascular plant plots (two soil cores of approx. 10 cm depth and 6 cm diameter from each of 4 plots per site) and the bryophyte plots (three soil cores of approx. 3 x 3 x 3 cm^3 from each plot per site). In the second survey, we collected from each plot one soil sample (approx. 5 x 5 x 10 cm^3). The soil samples were dried as soon as possible at 70ºC (first survey: 40ºC) to constant weight. Stones and roots were removed and the soil was pulverized with an electronic mill. The soil pH was measured from water suspension 1:3 soil/deionized water (w/v) of approx 1 g soil. After mixing, test tubes were left untouched for 24 hours before measurement (pH-meter 'Knick 761 Calimatic', Knick, Berlin, Germany).

Statistical analyses

We used mixed-model analysis of variance (ANOVA) to analyze effects of management, altitude, survey date (1995/97 vs. 2005/06) and their interactions on the response variables. Fixed effects of management and altitudinal class and their interactions were tested against the random effects of sites. Interactions between these factors and survey date were tested against the site x survey date interaction (random), and random effects of site and of the site x survey date interaction were tested against the residual variation between plots. If residuals were not homogeneously and normally distributed, we transformed the response variable (square root for counts, logarithm for continuous values, Sokal & Rohlf, 1995). We omitted one fen from the analyses because management changed from grazing to mowing between 1995 and 2005/06. For the same reason, we had to omit one plot from another fen in which management changed on part of the area of the site. The total number of replicates was thus only 348 instead of 360. For the analyses of vascular plant biomass and pH measured on the vascular plant plots, the total number of replicates was 313 because sampling was done on only four plots per site in the first survey. Because vascular plant biomass may strongly vary between years, we tested by t-tests whether differences between 1995 and 2005 (24 sites) and between 1995 and 2006 (12 sites) were consistent. All analyses were done with the statistical software R (version 2.6.0., R Development Core Team, 2007).

Results

Taxonomic-functional groups of vascular plants and bryophytes

Species density (= species number per 2 m^2) of all vascular plants did not change between the two surveys, but species density of herbs increased slightly over the 10-y period (18.8 ± 0.42 SE → 19.9 ± 0.44 SE; Table 2). Species density of legumes remained almost constant in grazed fens (1.67 ± 0.12 → 1.61 ± 0.13; Table 2), but increased in mown fens (2.04 ± 0.12 → 2.42 ± 0.13; Table 2). Overall, species density of vascular plants was 14.5% lower in grazed than in mown fens (Fig. 1A, Table 2). This difference was mainly due to negative effects of grazing on species density of herbs (Fig. 1C, Table 2), and, to a lesser degree, legumes (Fig. 1B). Altitude had no effect on species density of any of the four taxonomic-functional groups of vascular plants (Table 2).

Species density of bryophytes declined from 1997–2005/06 (12.2 ± 0.26 → 11.5 ± 0.23; Table 2). Management and altitude had no significant effects on total bryophyte species density (Table 2), but the interaction between these two factors was significant (Fig. 2A, Table 2). The decline of the bryophytes was mainly due to a decline in species density of mosses in grazed fens (grazed fens: 11.0 ± 0.34 → 10.1 ± 0.27, mown fens: 11.8 ± 0.31 → 11.7 ± 0.29; Table 2). In contrast to mosses, liverworts were slightly favoured by grazing (Table 2, Figs. 2B, C). However, for the liverworts, there was also a significant interaction between management and altitude with species density being generally low in mown fens and in grazed fens at low altitude, but high in grazed fens at higher altitudes (Fig. 2C).

Specialists, generalists and Red-List species of vascular plants and bryophytes

Over the 10-y period, species density of habitat specialists decreased by 9.4% in vascular plants (8.6 ± 0.23 → 7.8 ± 0.21; Table 3) and by 14.9% in bryophytes (4.4 ± 0.15 → 3.7 ± 0.15; Table 2). Density of vascular plant species of the Red List per 2 m^2 plot declined even by 22.7% (1.01 ± 0.07 → 0.78 ± 0.06; Table 3, Figs. 3A, B). The number of Red-List bryophyte species could not be analyzed, because too few plots contained such species. At both survey dates, species density of vascular plant specialists (but not of Red-List species) increased with altitude (low: 6.3 ± 0.20, intermediate: 8.8 ± 0.28, high altitude: 9.4 ± 0.26; Table 3). Management did not affect the reduction of specialist species density in vascular plants but in bryophytes specialist species density declined more strongly in grazed than in mown fens (Fig. 3C, Table 3). Species density of vascular plant generalists increased by 8.2% over the 10-y period (23.8 ± 0.49 → 25.7 ± 0.57) and was 16% lower in grazed (22.5 ± 0.49 species per plot) than in mown fens (26.8 ± 0.53 species per plot; Table 3). Species density of bryophyte generalists did not change over time and was not affected by management (Table 3).

Ecological groups based on indicator values

Between the two surveys, mean species density of nutrient indicators increased by 18.4% (13.6 ± 0.40 → 16.1 ± 0.48) and of peat indicators decreased by 8.1% (3.7 ± 0.12 → 3.4 ± 0.12; Table 4, Figs. 4A, B). Species density of wet-soil indicators decreased over the 10-y period in grazed (16.9 ± 0.33 → 15.7 ± 0.34), but not in mown fens (16.9 ± 0.35 → 17.1 ± 0.34; Table 4). No changes were found for the species density per plot of light indicators and of indicators of acidic soils (Table 4).

Species density of wet-soil indicators was particularly low at the lowest altitude (low: 15.5 ± 0.30, intermediate: 17.4 ± 0.25, high altitude: 17.2 ± 0.31; Table 4) indicating more disturbed hydrological conditions in these fens. Species density of light indicators increased with altitude in mown fens, but in grazed fens species density reached a maximum at intermediate altitude (mown fens: low: 19.6 ± 0.47, intermediate: 21.3 ± 0.49, high altitude: 23.3 ± 0.58; grazed fens: low: 16.3 ± 0.53, intermediate: 21.1 ± 0.57, high altitude: 17.5 ± 0.41, Table 4).

Community biomass, pH and mean indicator values of vascular plants

In the second survey, aboveground biomass of vascular plants was almost 30% higher than in the first survey (254 ± 9.9 g m^{-2} → 329 ± 10.4 g m^{-2}; Table 5). Because in the second survey we sampled biomass in 2005 (24 fens) and in 2006 (12 fens), we tested whether both years had a higher vascular plant biomass than 1995; and this was the case (2005: $t = 3.24$, $p = 0.001$; 2006: $t = 3.90$, $p < 0.001$; Fig. 5). There was also a significant interaction between management and altitude, which was mainly caused by the very low biomass values in the grazed fens at the lowest altitude (Table 5). The soil-pH in the second survey (6.00 ± 0.05) was slightly but significantly ($p < 0.05$) lower than in the first survey (vascular plant survey in 1995: 6.12 ± 0.05; bryophyte survey in 1997: 6.08 ± 0.04, Table 5).

Over the 10-y period, mean plant indicator values changed significantly in the direction of reduced habitat quality for originally nutrient-poor fens (Table 6): indicator values for soil moisture, light availability, soil acidity and organic content of soils decreased whereas indicator values for soil nutrients increased (Fig. 6). In grazed fens, mean soil moisture values indicated wetter conditions than in mown fens (grazed fens: 3.72 ± 0.012, mown fens: 3.63 ± 0.011; Table 6) and average indicator values for light availability were higher at higher altitudes (low: 3.60 ± 0.012, intermediate: 3.64 ± 0.012, high altitude: 3.69 ± 0.011; Table 6).

Discussion

Decline of habitat specialists and Red-List species

Despite protection and traditional management, fen specialists of both vascular plants and bryophytes declined in the studied fens over a 10-y period even at the small spatial scale of 2 m^2. In vascular plants, the relative decline was stronger for species of the Red List, emphasizing the higher extinction probability of these species. Declines in species richness of habitat specialists over a 5-y period have been reported for different types of bogs in Switzerland (Klaus, 2007). Reduced richness of specialist species was also reported from other species-rich, semi-natural wet grassland habitats in Europe (Kooijman, 1992; Fojt and Harding, 1995; van Belle et al., 2006), but not over such short time spans as in this study. From a conservation point of view, the clear decline of habitat specialists in our case is particularly worrying because the sites are still traditionally managed. Moreover, because we only considered plots that contained the characteristic fen specialist *Carex davalliana*, i.e. plots or fen patches which lost this sedge were not even considered for monitoring, our estimates of the decline of habitat specialists and Red-List species may even be too conservative.

Causes of decline

The decline in habitat specialists and Red-List species at the study sites was correlated with a decline in habitat quality. The increased aboveground vascular plant biomass, changes in mean plant indicator values, the increase of nutrient indicators per plot and the decrease of peat indicators point to eutrophication and decreasing moisture: the fens became more productive, richer in nutrients, shadier at the ground and drier, thus making it difficult for small, non-competitive, fen-adapted species to survive. This decline in habitat quality is not specific to calcareous fens. Similar trends have also been observed in acidic fens and bogs and other habitats in Switzerland (Klaus, 2007; Stöcklin et al., 2007). In the following we discuss which factors could cause such effects.

Nutrient enrichment is widely recognized as an important driver of vegetation change in various types of wetlands (DiTommaso and Aarssen, 1989; Bobbink et al., 1998; Bedford et al., 1999) and it has been shown that both nitrogen and phosphorous can limit above-ground biomass in fens (Verhoeven et al., 1996; Boeye et al., 1997; Pauli et al., 2002). Lowered light availability under more productive conditions has been suspected to be the main reason for the decrease of fen specialist species (Kotowski et al., 2001), although increased belowground competition may also contribute (Rajaniemi, 2002). In our calcareous fens, it has been experimentally shown that nutrient enrichment reduced bryophyte species density and biomass and increased vascular plant biomass within 1.5 years after application of either nitrogen alone or of a mixture of nutrients (NPK, Bergamini and Pauli, 2001; Pauli et al., 2002). Although Pauli et al. (2002) did not find a decrease in the number of habitat specialists during the course of their short-term experiment, they already observed an increase in generalist species, which might have outcompeted the specialists in the longer term. In our study, the increase of the mean nutrient indicator value was caused by two processes: the decrease of habitat specialists and the increase of nutrient indicator species. The decrease of bryophyte species density in our study was likely caused by eutrophication that led to an increase of vascular plant biomass, but not of bryophyte biomass (see also

Virtanen et al., 2000; van der Wal et al., 2005). Due to the experimentally shown N-limitation of aboveground biomass production in our fens (Pauli et al., 2002), high atmospheric nitrogen deposition has the potential to cause the observed changes (see also Stevens et al., 2004). Atmospheric nitrogen deposition rates in Switzerland exceed critical loads in 55% of the area covered with natural or semi-natural non-forest vegetation (BAFU / BFS, 2007). In the study region, deposition rates reach up to 40 kg ha^{-1} y^{-1} (BAFU / BFS, 2007). Theoretically, increased phosphorus input could also lead to the observed changes, but given the diminished solubility of phosphates under base-rich conditions (Verhoeven et al., 1996; Larcher, 2003), this seems rather unlikely. However, phosphorus may also be released from microbes after drying and rewetting of the soil and it has been hypothesized that this process enhances the availability of phosphorus in regions with longer dry periods or more frequent cycles of wetting and drying due to climate change (Turner and Haygarth, 2001).

To assess whether the observed biomass increase was related to climatic differences between censuses (Knapp & Smith, 2001), we compared climatic data (daily precipitation and daily mean temperatures) from three weather stations within the study area (Alpthal: 1220 m a.s.l., Einsiedeln: 910 m a.s.l., Ebnat-Kappel: 623 m a.s.l.) for each month from March to August between 1995 (first survey) and 2005/2006 (second survey). Concerning precipitation, none of the mean daily amounts in the different months in 1995 was significantly different from those in 2005 or 2006 (Wilcoxon rank sum tests, data not presented). However, mean daily temperature in June (main growth period in these pre-alpine fens) 1995 was between 3.8º and 2.9º C lower than in June 2005 and June 2006 at all three weather stations (Wilcoxon rank sum tests: $P < 0.01$ for all comparisons). Besides these rather extreme differences, there is a trend to increased temperatures during the growing period with a mean temperature increase per decade and month between 0.45ºC and 0.75ºC as regressions analyses for the period 1970–2006 showed for two of the weather stations ($P < 0.05$ in Ebnat-Kappel for April, May and June; in Einsiedeln for April, May, June, July and August; for Alpthal there were no long-term data available). If temperature, besides eutrophication, was the main driver of aboveground plant biomass production in these fens, then the predicted higher June temperatures for the coming decades (OcCC, 2007) may further increase fen productivity and threaten habitat specialists.

Lowering of the soil moisture is disastrous for fen vegetation (e.g. Grootjans et al., 2005), especially when combined with increased nutrient input (Fojt and Harding, 1995; Bollens et al., 2001). Although drainage is rarely part of the management contracts (Gonet, 2002), we observed in nearly every fen studied some traces of rather old (most probably built before legal protection of fens in Switzerland, i.e. before 1987), but still active drainage channels. However, there were no newly built channels. In addition to direct drainage of fens, disturbance of the hydrological regime in the surroundings of fens may also have severe effects on soil moisture within fens (Fojt and Harding, 1995; van Diggelen et al., 2006). Hence, altered hydrological site conditions may be one of the causes of the observed decline in mean soil-moisture indicator values. As for eutrophication effects, effects of changed hydrological conditions on fen specialists may also be mediated by increased biomass production of generalist, dominant vascular plants benefiting from those changes. The decreased organic content of the soil can also be a direct cause of the lowered soil moisture as well as of other processes such as increased atmospheric nitrogen deposition or global warming known to stimulate microbial decomposer communities and thus to enhance decomposition rates of organic material (Heimann and Reichstein, 2008). Furthermore, the lowering of the water table in fens increases the relative importance of rainwater, which may lead to an acidification of the uppermost soil layer (van Diggelen et al., 2006). This may explain the decrease of the mean indicator values for acidity and of measured pH values over the last decade in the studied fens.

Effects of management and altitude on species density and habitat quality

Vascular plants

Although both forms of traditional management, grazing and mowing, are considered appropriate for these fens, each of the two has its specific effects on species composition and richness. Thus, the species density of all vascular plants was consistently higher in mown fens (see also Peintinger, 1999), but habitat specialists and Red-List species of vascular plants were not affected by management. These results are consistent with those of Stammel et al. (2003) from calcareous fens in southern Germany. In drier grassland sites low-intensity grazing has usually a positive or neutral effect on total vascular species density (Olff and Ritchie, 1998; Schläpfer et al., 1998; Fischer and Wipf, 2002). On wet soils, especially the effects of trampling on sensitive species may be much more severe than on dry soil (we observed gaps created by cattle hoofs of up to a depth of 25 cm in our fens, A. Bergamini et al., unpublished data) and the loss of these species may not be adjusted by the colonisation of gap depending species. For example Stammel & Kiehl (2004) found no species in hoofprints in fens which have not already been present in the surrounding vegetation and they found hardly any positive effects of hoofprints on species recruitments (see also Stammel et al., 2006). However, there are also reports of positive effects of artificially created gaps in fens on vascular plant germination (Kotorová and Leps, 1999; Poschlod and Biewer, 2005), but these artificially created gaps are presumably not directly comparable to hoofprints with their compacted and wet or even water-logged soil on the bottom. On dry soils, the creation of small disturbances by trampling, the spatially heterogeneous urine deposition and the selective defoliation by grazing ungulates all cause high habitat heterogeneity and are presumably responsible for the often positive effect on species density (van Wieren, 1995; Olff and Ritchie, 1998; Middleton et al., 2006). In our fens, the negative effect of grazing on vascular plants was mainly due to the decrease in species density of herbs and legumes; graminoid species were not affected, presumably due to selective grazing and better abilities for compensatory growth after trampling of grasses because of their basal meristems in contrast to legumes and herbs.

Bryophytes

Species density of different bryophyte groups was differentially affected by management: grazing enhanced liverwort and mowing enhanced moss species density. In contrast to vascular plant specialists, which showed a similar decline over the 10-y study period both in grazed and mown fens, mosses and specialist bryophyte species declined strongly in grazed fens, but less so in mown fens. Separate ANOVAs (data not shown) showed that the differential decline for mosses was due to the specialists among them without a compensating response of generalist mosses. Whether the stronger decrease of the bryophyte habitat specialists in the grazed fens can be considered an early warning signal for similar changes in the vascular plant layer remains to be seen.

Liverwort species such as *Pellia endiviifolia*, *Riccardia multifida* or *Scapania* species were often found on the border and on the often steep walls of the small gaps created by the hoofs of the grazing cattle (A. Bergamini et al., unpublished data). Within the dense and thick moss layer of mown meadows however, liverworts were rarely found. In the lowest altitudinal class, grazing had a slightly negative effect on species density of liverworts. The reasons for this different effect of grazing on liverwort species density in the lowest altitudinal class are not clear.

Management and altitude also had differential effects on habitat quality. Average indicator values indicated that grazed fens were wetter than mown fens, an observation also reported by Barth et al. (2000) and Stammel et al. (2003) and probably due to the compaction of the soil by the grazing animals. With increasing altitude, habitat quality of fens increased somewhat as indicated by the increasing average indicator value for light availability and the increase in species density of vascular plant specialists.

Conclusions

Despite traditional management, habitat quality and species density of habitat specialists and Red-List species of calcareous fens in the Swiss pre-Alps significantly decreased over only a decade from 1995–2006. The stronger decline of bryophyte habitat specialists in grazed fens than in mown fens may indicate that the current grazing intensity (but probably not grazing per se) is not a suitable conservation measure for these fens. Furthermore, specialized vascular wet-soil indicator plants declined only in grazed fens. On the other hand, grazed fens still contained many vascular plant and bryophyte species of high conservation value (see also Barth et al., 2000). Thus, also grazed fens are still important objects for fen conservation. A number of species are even dependent on grazed sites. For example, the dung mosses *Splachnum ampullaceum* and *Splachnum sphaericum*, which grow only on decaying cattle feces in fens and bogs (Amann et al., 1918), are obviously not found in mown fens. Considering vascular plants, the herb *Ranunculus flammula* and the grass *Agrostis canina* are examples of species of conservation concern (both with Red-List status 'nearly threatened') which are mostly found in grazed sites.

Based on our diversity monitoring, the following recommendations can be made for long-term protection of these fens: (1) the traditional management has to be continued since abandoned fens loose habitat specialists (Diemer et al., 2001; Peintinger and Bergamini, 2006); however, grazing intensity (cattle breed, animal weight, stocking rate) should be adjusted to sustainable levels; (2) nutrient inputs should be reduced via the inclusion of unfertilized buffer zones around fens and measures that reduce atmospheric input of nutrients; (3) the often disturbed hydrology should be restored also in consideration of the predicted significant decrease in summer rains and increase of summer temperatures (OcCC, 2007) in the region, which will enhance the fragility of these specialized ecosystems adapted to high groundwater tables. Hydrological buffer zones around the fens may be an effective measure for the long-term protection of these fens.

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Figure Captions

Fig. 1. Species density in 1 x 2 m plots of vascular plants (A), legumes (B) and herbs (C) as a function of management and altitude in calcareous fens. Values are means over both survey dates (± SE). Altitudinal class 1: 800–1000 m a.s.l.; altitudinal class 2: 1000–1200 m a.s.l.; altitudinal class 1: 1200–1400 m a.s.l. Species density of vascular plants, legumes and herbs was lower in grazed than in mown fens ($F_{1,29} = 12.57$, $P < 0.001$, $F_{1,29} = 6.87$, $P < 0.05$ and $F_{1,29} = 20.56$, $P < 0.001$, respectively).

Fig. 2. Relationships between species density of bryophytes (A), mosses (B) and liverworts (C) and management and altitude (means over both survey dates ± SE). Altitudinal class 1: 800–1000 m a.s.l.; altitudinal class 2: 1000–1200 m a.s.l.; altitudinal class 1: 1200–1400 m a.s.l. Effects of management were significant for mosses ($F_{1,29} = 7.23$, $P < 0.05$), and marginally significant for liverworts ($F_{1,29} = 3.97$, $P < 0.06$). For both bryophytes and liverworts the management x altitude interaction was significant ($F_{2,29} = 3.59$, $P < 0.05$ and $F_{2,29} = 3.36$, $P < 0.05$, respectively)

Fig. 3. Effects of survey date on species density of vascular plant habitat specialists (A) and Red- List species (B), and effects of survey date and management type on bryophyte habitat specialists (C; means ± SE). Habitat specialists and Red-List species all significantly declined 1995/97 → 2005/06 (Table 3). Bryophyte specialists declined especially in grazed fens ($F_{1,29}$=4.74, P<0.05).

Fig. 4. Increase of average species density per plot of nutrient indicators (A) and concomitant decrease of peat indicators (B) 1995 → 2005/06 (means ± SE). Only vascular plants are considered.

Fig. 5. Aboveground biomass of vascular plants significantly increased between the first and the second survey (means ± SE; $F_{1,29}$=25.44, P<0.001). The second survey was done in the years 2005 (24 sites) and in 2006 (12 sites).

Fig. 6. Changes in mean indicator values for soil moisture (A), light availability (B), soil nutrients (C), soil acidity (D) and soil organic content (E) after Landolt (1977) between the two surveys (means ± SE).

Table 1 All species designated as habitat specialists for vascular plants (after BUWAL, 1990) and bryophytes (see Methods section). Nomenclature for vascular plants follows Lauber & Wagner (2001) and for mosses Hill *et al.* (2006). * incl. *Campylium protensum*

Vascular plants	**Bryophytes**
Aster bellidiastrum	*Brachythecium mildeanum*
Bartsia alpina	*Brachythecium turgidum*
Calycocorsus stipitatus	*Breidleria pratensis*
Carex capillaris	*Bryum pseudotriquetrum*
Carex davalliana	*Calliergon giganteum*
Carex dioica	*Campylium stellatum**
Carex flava	*Cinclidium stygium*
Carex hostiana	*Fissidens adianthoides*
Carex panicea	*Hamatocaulis vernicosus*
Carex pulicaris	*Meesia triquetra*
Eleocharis quinqueflora	*Palustriella decipiens*
Epipactis palustris	*Palustriella falcata*
Eriophorum latifolium	*Philonotis calcarea*
Juncus alpinoarticulatus	*Plagiomnium elatum*
Molinia caerulea	*Pseudocalliergon trifarium*
Parnassia palustris	*Scorpidium cossonii*
Pinguicula alpina	*Sphagnum contortum*
Pinguicula vulgaris	*Sphagnum warnstorfii*
Primula farinosa	*Tomentypnum nitens*
Schoenus ferrugineus	
Selaginella selaginoides	
Swertia perennis	
Tofieldia calyculata	
Trichophorum cespitosum	
Triglochin palustris	

Table 2 Results of mixed-model ANOVAs on the effects of management, altitude, date of survey and of interactions between these factors on species density of different taxonomic/functional groups in 1 x 2 m plots. Species density of liverworts was square-root transformed prior to analysis. +: P < 0.06; *: P < 0.05; **: P < 0.01; ***: P < 0.001.

		All vascular plants			**Sedges**			**Grasses**			**Legumes**		
	df	**SS**	**F**		**SS**	**F**		**SS**	**F**		**SS**	**F**	
Management (M)	1	2291.2	12.57	***	28.41	2.98		0.69	0.05		30.91	6.87	*
Altitude (A)	2	669.1	1.84		57.08	2.99		44.74	1.60		21.88	2.43	
M x A	2	840.3	2.30		17.41	0.91		14.85	0.53		18.16	2.02	
Site (S)	29	5287.8	7.24	***	276.65	3.27	***	406.21	5.70	***	130.41	4.66	***
Date of survey (D)	1	116.1	3.14		10.00	2.85		6.08	2.18		2.42	2.68	
M x D	1	117.5	3.18		0.49	0.14		0.44	0.16		4.15	4.60	*
A x D	2	183.1	2.48		3.55	0.51		1.49	0.27		2.73	1.51	
A x M x D	2	16.4	0.22		4.21	0.60		1.18	0.21		0.83	0.46	
S x D	29	1071.4	1.47		101.75	1.20		80.83	1.14		26.18	0.94	
Residuals	278	6999.2			811.10			682.75			268.30		
		Non-legume herbs			**All bryophytes**			**Liverworts**			**Mosses**		
	df	**SS**	**F**		**SS**	**F**		**SS**	**F**		**SS**	**F**	
Management (M)	1	2191.1	20.56	***	38.6	1.81		5.29	3.97	+	119.9	7.23	*
Altitude (A)	2	568.6	2.67		80.8	1.90		6.55	2.46		42.8	1.29	
M x A	2	519.3	2.44		152.6	3.59	*	8.95	3.36	*	73.4	2.21	
Site (S)	29	3090.6	7.57	***	617.4	2.35	***	38.60	4.26	***	481.0	2.30	***
Date of survey (D)	1	98.3	5.31	*	33.5	6.02	*	1.04	2.98		22.3	5.15	*
M x D	1	55.3	2.98		13.2	2.37		0.41	1.18		18.0	4.16	*
A x D	2	94.8	2.56		3.7	0.33		0.10	0.14		2.8	0.32	
A x M x D	2	33.1	0.89		3.8	0.35		2.14	3.07		7.0	0.81	
S x D	29	537.4	1.32		161.6	0.62		10.09	1.11		125.2	0.60	
Residuals	278	3911.5			2516.3			86.85			2003.4		

Table 3 Relationships between management, altitude, date of survey and of interactions between these factors on species density of habitat specialists, generalists and density of Red-List species in 1 x 2 m plots. *: P < 0.05; **: P < 0.01; ***; P < 0.001.

Vascular plants										
		Habitat specialists			**Red-List species**			**Generalists**		
	df	**SS**	**F**		**SS**	**F**		**SS**	**F**	
Management (M)	1	61.6	2.36		10.79	3.52		1601.7	7.32	*
Altitude (A)	2	617.4	11.82	***	1.55	0.25		472.8	1.08	
M x A	2	113.9	2.18		2.69	0.44		401.5	0.92	
Site (S)	29	757.4	5.68	***	88.88	6.63	***	6342.8	8.49	***
Date of survey (D)	1	56.3	11.31	**	4.60	6.11	*	334.1	10.71	**
M x D	1	8.6	1.74		0.13	0.17		62.4	2.00	
A x D	2	26.1	2.62		0.42	0.28		75.1	1.20	
A x M x D	2	26.5	2.66		0.87	0.58		10.8	0.17	
S x D	29	144.4	1.08		21.81	1.63	*	904.6	1.21	
Residuals	278	1278.6			128.55			7159.4		

Bryophytes							
		Habitat specialists			**Generalists**		
	df	**SS**	**F**		**SS**	**F**	
Management (M)	1	4.91	0.31		15.99	0.53	
Altitude (A)	2	32.05	1.00		30.83	0.51	
M x A	2	0.27	0.01		143.03	2.37	
Site (S)	29	463.93	6.13	***	875.62	3.56	***
Date of survey (D)	1	37.35	17.12	***	0.10	0.01	
M x D	1	10.33	4.74	*	0.18	0.02	
A x D	2	0.15	0.03		5.19	0.35	
A x M x D	2	0.81	0.19		3.52	0.24	
S x D	29	63.26	0.84		217.12	0.88	
Residuals	278	725.80			2358.70		

Table 4 Dependence of species density of wet-soil indicators, light indicators, rich-soil indicators, indicators of acidic soils and peat indicators in 1 x 2 m plots on management, altitude, date of survey and the interactions between these factors. Classification of species was based on the indicator values of Landolt (1977). *: P < 0.05; **: P < 0.01; ***: P < 0.001.

Species density of indicators of																
		Wet soil			**Light**			**Soil nutrients**			**Acidity**			**Peat**		
	df	**SS**	**F**		**SS**	**F**		**SS**	**F**		**SS**	**F**		**SS**	**F**	
Management (M)	1	43.6	1.62		946.3	17.35	***	602.9	3.78	+	0.9	0.01		0.0	0.00	
Altitude (A)	2	250.7	4.65	*	619.0	5.67	**	349.6	1.10		44.1	0.45		13.6	0.51	
M x A	2	107.5	1.99		439.9	4.03	*	220.7	0.69		0.6	0.01		1.1	0.04	
Site (S)	29	782.2	3.55	***	1582.1	5.18	***	4625.8	8.54	***	1433.4	12.80		387.5	8.92	***
Date of survey (D)	1	17.0	2.09		13.7	0.79		546.3	27.50	***	0.7	0.32		8.4	5.31	*
M x D	1	46.9	5.75	*	45.2	2.60		50.9	2.56		1.6	0.79		0.0	0.00	
A x D	2	19.5	1.19		74.2	2.13		88.4	2.23		5.6	1.40		1.2	0.37	
A x M x D	2	15.2	0.93		9.6	0.28		1.0	0.02		1.3	0.33		3.8	1.19	
S x D	29	236.7	1.07		504.8	1.65	*	576.0	1.06		58.3	0.52		45.8	1.06	
Residuals	278	2113.1			2930.8			5190.7			1073.2			416.3		

Table 5 Effects of management, altitude, date of survey and their interactions on aboveground vascular plant biomass in 18.5 x 18.5 cm^2 plots and on pH measurements. There were only 243 degrees of freedom for the residuals because in 1995 biomass and pH was sampled only on 4 plots per site. In addition, for pH there were four missing values in 2005/06. Biomass was log-transformed for the analysis. *: P < 0.05; ***: P < 0.001.

		Biomass			pH		
	df	**SS**	**F**		**SS**	**F**	
Management (M)	1	0.47	0.98		0.26	0.15	
Altitude (A)	2	4.33	4.55	*	0.20	0.06	
M x A	2	3.69	3.87	*	2.46	0.71	
Site (S)	29	13.80	3.04	***	50.04	9.70	***
Date of survey (D)	1	6.58	25.44	***	1.19	5.00	*
M x D	1	0.05	0.20		0.00	0.01	
A x D	2	0.14	0.27		0.00	0.00	
A x M x D	2	0.43	0.83		0.01	0.03	
S x D	29	7.50	1.65	*	6.90	1.34	
Residuals	243/239	38.00			42.52		

Table 6 Relationships between mean indicator values per plot after Landolt (1977) and management, altitude, date of survey and their interactions. Mean indicator values are based on vascular plant vegetation only. *: P < 0.05; **: P < 0.01; ***: P < 0.001.

		Moisture			Light			Nutrients			Acidity			Peat		
	df	SS	F		SS	F		SS	F		SS	F		SS	F	
Management (M)	1	0.72	11.91	**	0.03	0.54		0.01	0.06		0.22	0.74		0.09	1.21	
Altitude (A)	2	0.25	2.03		0.50	4.67	*	0.92	2.33		0.90	1.56		0.12	0.85	
M x A	2	0.20	1.67		0.01	0.11		0.06	0.16		0.03	0.04		0.15	1.00	
Site (S)	29	1.76	3.71	***	1.54	5.45	***	5.76	9.74	***	8.40	13.59	***	2.16	7.00	***
Date of survey (D)	1	0.14	6.34	*	0.52	37.67	***	0.38	15.01	***	0.18	9.30	**	0.14	8.17	**
M x D	1	0.03	1.28		0.01	0.52		0.01	0.34		0.00	0.01		0.00	0.00	
A x D	2	0.02	0.47		0.04	1.37		0.02	0.36		0.01	0.36		0.05	1.38	
A x M x D	2	0.02	0.45		0.02	0.71		0.03	0.53		0.04	0.90		0.01	0.37	
S x D	29	0.64	1.35		0.40	1.42		0.74	1.24		0.57	0.92		0.50	1.65	*
Residuals	278	4.56			2.71			5.67			5.92			2.92		

Fig. 1

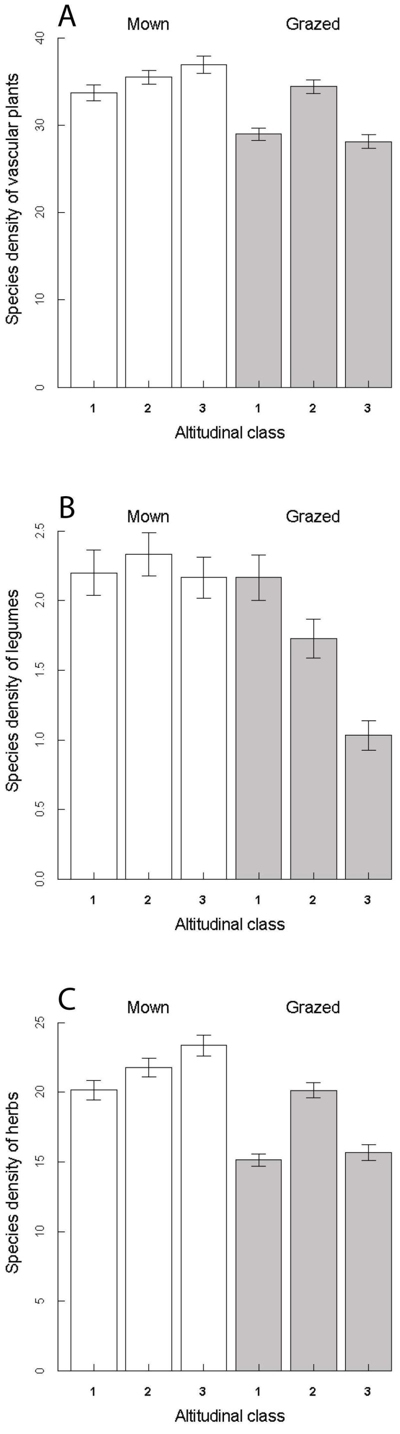

A
Mown
Grazed
Species density of vascular plants
0
10
20
30
40
1
2
3
1
2
3
Altitudinal class
B
Mown
Grazed
Species density of legumes
0.0
0.5
1.0
1.5
2.0
2.5
1
2
3
1
2
3
Altitudinal class
C
Mown
Grazed
Species density of herbs
0
5
10
15
20
25
1
2
3
1
2
3
Altitudinal class

Fig. 2

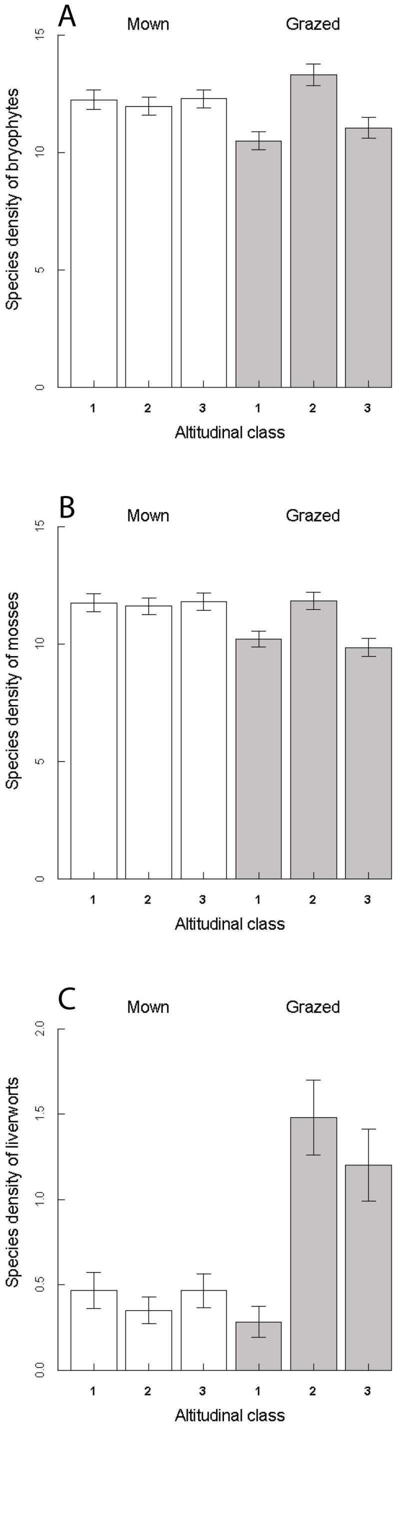

A
Mown
Grazed
Species density of bryophytes
0
5
10
15
1
2
3
1
2
3
Altitudinal class
B
Mown
Grazed
Species density of mosses
0
5
10
15
1
2
3
1
2
3
Altitudinal class
C
Mown
Grazed
Species density of liverworts
0.0
0.5
1.0
1.5
2.0
1
2
3
1
2
3
Altitudinal class

Fig. 3

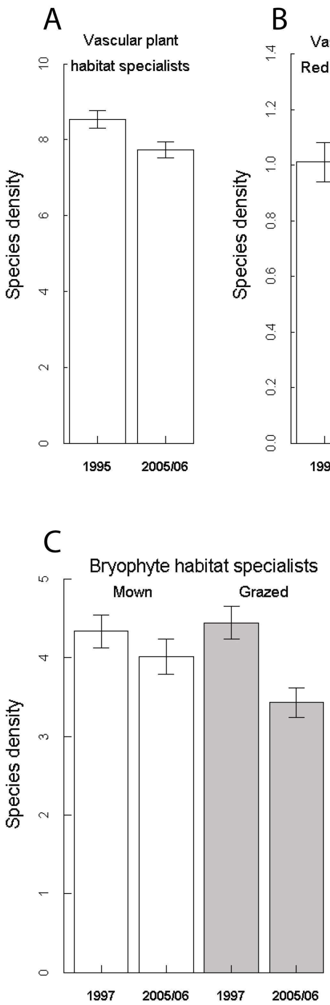

A
Vascular plant
habitat specialists
Species density
1995
2005/06
B
Vascular plant
Red List species
Species density
1995
2005/06
C
Bryophyte habitat specialists
Mown
Grazed
Species density
1997
2005/06
1997
2005/06

Fig. 4

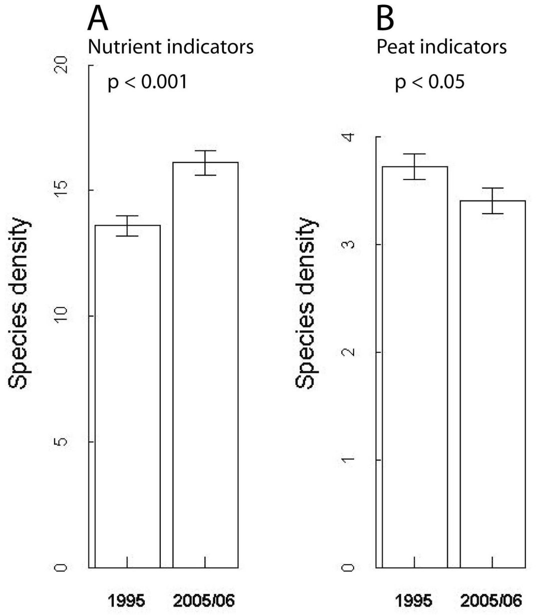

A
Nutrient indicators
p < 0.001
Species density
0
5
10
15
20
1995
2005/06
B
Peat indicators
p < 0.05
Species density
0
1
2
3
4
1995
2005/06

Fig. 5

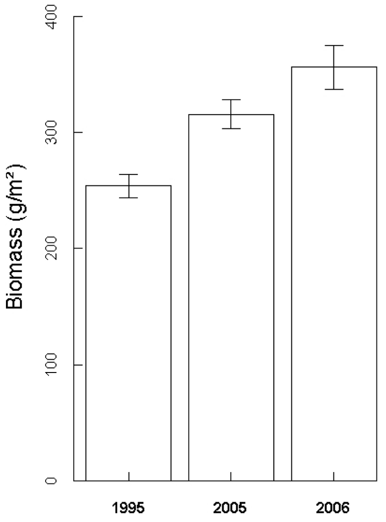
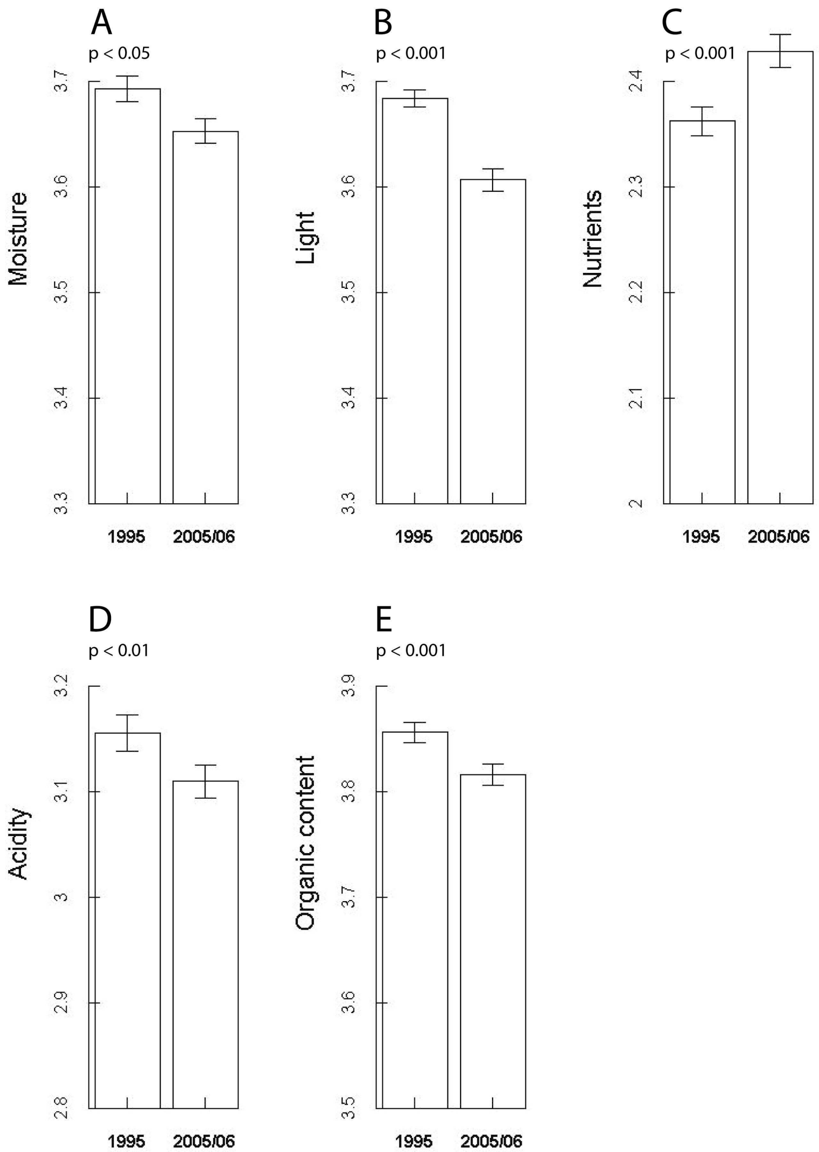


Fig. 6


A
p < 0.05
Moisture
3.3
3.4
3.5
3.6
3.7
1995
2005/06
B
p < 0.001
Light
3.3
3.4
3.5
3.6
3.7
1995
2005/06
C
p < 0.001
Nutrients
2
2.1
2.2
2.3
2.4
1995
2005/06
D
p < 0.01
Acidity
2.8
2.9
3
3.1
3.2
1995
2005/06
E
p < 0.001
Organic content
3.5
3.6
3.7
3.8
3.9
1995
2005/06

4

A perspective on the current state of Environmental Impact Assessment in Iran

Hossein Moradi, Jasmin Joshi, Bernhard Schmid

Abstract

Iran is a vast country subject to diverse climatic and environmental conditions and hence harbors an immense diversity of terrestrial and marine species. Many Iranian ecosystems are of international importance and there are several UNESCO Biosphere Reserves in the country. Therefore, environmental protection is of high concern in Iran.

During the past decades, great pressure has been put on environmental resources due to unsustainable development patterns. To achieve the goals of sustainable development, the accurate enforcement of environmental impact assessments (EIA) is needed. This paper reviews the history of environmental legislation in Iran and presents an evaluation of the current state of EIA and discusses limitations that the EIA process is facing.

National environmental protection legislation was enacted five decades ago with the formulation of the hunting law in 1956 and the establishment of the Hunting and Fishing Organization in 1967, subsequently renamed Department of the Environment (DoE) in 1972. The power and responsibilities of the DoE grew steadily and now it is affiliated with the President's Office and is administered by the Environmental Protection High Council (EPHC). The EPHC and the DoE are chaired by the same "Vice-President" that is directly appointed by the Iranian president. The legal basis for EIA in Iran was established by Note 82 of the "Law of the 2nd Development Plan" in 1994, amended by Note 105 of the "Law of the 3rd Development Plan", and implemented through Decree 138 of the EPHC in 1994.

Despite considerable progress that has been made in the past 14 years concerning the implementation of an EIA system in Iran, there are still several limitations in the procedure at different stages of an EIA. Obviously, similar problems exist in other countries; and EIA globally is still far from being perfect. There is a need of more clarity in the legal definitions of EIA and of the contents of Environmental Impact Statements (EISs). In addition, there is a quantitatively limited human resource capacity for reviewing the EIA reports. A higher consideration of alternatives of projects, enhanced effective public participation, more effective legal enforcement to enact the EIA report contents and more rigorous procedures to analyze the EIA data would help to conserve the rich biological heritage of Iran.

Keywords: Environmental Impact Assessments, EIA legal basis, Evaluation, Iran

1. Introduction

1.1. EIA systems in developing countries and the Middle East

The first environmental impact assessment (EIA) system was established in 1970 in the United States with the aim to change people's lives for the better (Wood, 2003a). The EIA system had the immediate purpose to enable developments and building projects that do not have "costs on earth" (Glasson, 2005).

Nowadays, over 100 EIA systems are globally implemented and EIA is accepted as one of the major environmental policy tools (Annandale, 2001). However, EIA systems are working differently depending on the level of development in a region. Therefore, there is a clear difference between developed countries and developing countries in EIA systems (Wood, 2003b). The origin of the difference among developed and developing countries can be attributed to the formalization process of the EIA that in developing countries was implemented by development assistance agencies (Annandale, 2001; Wood, 2003b). However, even among developing countries, the EIA systems are different. George (2000) mentioned the reasons of this variety as "differences in political and administrative systems, social and cultural systems, the level and nature of economic development and differences in climate, ecology, resources." Glasson (2000) considered "socio-cultural conditions, traditions, hierarchies, and social networks" as the reasons leading to different EIA systems in developing countries.

The Middle East is characterized by its richness in oil and gas, but lack of resources in renewable water and arable land (El-Fadl, 2003). In MENA countries (21 countries in the Middle East and North Africa), the similarity of climate, resources and socio-cultural conditions among the countries results in similar types of development projects with similar qualitative environmental impacts but different magnitudes and severities of impacts. The World Bank named the main problems of MENA countries as (a) water scarcity and quality, (b) land degradation and desertification, (c) coastal degradation, (d) urban and industrial pollution and (e) weak institutional and legal frameworks (World Bank, 2001). Water scarcity, land degradation and desertification cause a declining potential for agriculture and the traditional life-style and increase migration to the mega-cities. Hence, political will to consider environmental issues is needed to govern economic development towards minimal environmental costs (Glasson, 2000).

Environmental impact assessment (EIA) was first introduced in the Middle East in 1982 in Oman. Most other countries in the Middle East introduced EIA in the 1990s. In general, the EIA systems in developing countries suffer from a range of limitations and inadequacies. Glasson (2000) mentioned the lack of an open decision making process, the confidentiality of EIA reports, weak or non-existent public participation, lack of trained personnel, poor implementation and compliance with regulations, as well as limited or non-existent environmental monitoring. In addition, EIA systems often are poorly integrated with development plans, in which they are, if ever, only considered late in the planning process Glasson (2000). Unfortunately, EIA systems in developing countries are rarely reviewed and revised to find their strengths and limitations, and to use the knowledge gained to change the system in an effective way.

EIA was introduced in Iran in 1994. The aim of this paper is to review the strengths and limitations of the EIA system in Iran after 14 years of experience and to identify target elements within the EIA system to improve its effectiveness.

2. Context, institutional and legal basis for EIA in Iran

2.1. *Iran in context*

Iran comprises a land area of 1.64 million km^2 located in the northern temperate zone between 25° and 40° North and 44° and 63° East. The average altitude is above 1200 m a.s.l. The country features three main climatic zones: arid and semi-arid regions of the interior and far south, which are characterized by long, warm and dry periods, lasting sometimes over 7 months, and covering nearly 90% of the country (CBD, 2005). The annual precipitation in such regions varies from 30–250 mm. Mediterranean climate (mainly in the western Zagros mountains, the high plateau of Azerbaijan, and the Alborz mountains), characterized by warm, dry summers and cool, damp winters, with annual rainfall from 250–600 mm, covers about 5% of the land surface. Humid and semi-humid regions (mainly in the Caspian, but also in west Azerbaijan and the southwest Zagros region), with an annual precipitation rate of 600–2000 mm also cover about 5% of the land surface (CBD, 2005; Noroozi et al., 2008).

The relief and climatic variations have given rise to five biomes, namely:

- Irano-Touranian Plains (ITP): arid and semi-arid plains and desert

- Irano-Touranian Mountains (ITM): arid and semi-arid mountains
- Zagrosian (Z): semi-arid Zagros mountains
- Hyrcanian (H): semi-humid and humid Arasbaran and Hyrcanian mountains and Caspian plain
- Khalijo-Ommanian (KO): dry southern coastal plains with high humidity

Based on the different biomes, 11 main bio-climatic zones are distinguishable in Iran: Caspian zone < 800 m, Caspian zone > 800m, sea (Caspian sea, Persian gulf and Oman sea) and freshwater lakes, main salt lakes and Kavirs, highest mountains, xerophilous forest zone, semi-steppic zone, steppic zone, subdesertic zone, Baluchi zone (FAO, 2004). In addition, Iran contains parts of the Caucasus and Northeast Anatolia temperate forests, the Middle-Asian mountain temperate forests, the Mesopotamian delta and marshes, and the Oman Sea and Persian Gulf (WWF, 1999). This diversity of bio-climatic zones is related to a large range of elevations from below to 5610 m above sea level and temperatures from –44 ºC to 56 ºC. The many different types of ecosystems harbor a tremendous diversity of unique, endemic and endangered species. For example, the Persian Gulf is the habitat of the biggest mammal of the world (Blue Whale), while the second smallest mammal in the world, the Pygmy White-Toothed Shrew, lives in terrestrial habitats in Iran (Earthlife, 2007). There are 12.4 million hectares of woodland, and some 8,900 hectares of *Avicenna* mangroves along the Persian Gulf coast (CBD, 2005). Iranian habitats support more than 8200 plant species (a conservative estimate), of which 1900 are endemic (CBD, 2005). Field studies confirmed the presence of over 500 species of birds and 160 species of mammals (CBD, 2005).

In Iran, areas protected by the Department of Environment (DoE) cover 8.5 million hectares (about 5% of the land area). The total area of National parks (11 sites) is 1.3 million hectares; Wildlife refuges (25 sites) cover 1.9 million hectares, and protected areas (47 sites) 5.3 million hectares (0.79%; 1.16% and 3.23% of the country's area, respectively; CBD, 2005). Iran has five National Nature Monuments and nine UNESCO Biosphere Reserves. One of the National Parks, nine of the Wildlife Refuges and ten of the Protected Areas were established primarily to protect wetland ecosystems, while a further two Protected Areas and a Wildlife Refuge incorporate important wetland habitat. In Iran, 22 wetlands out of the 63 internationally important wetlands are identified as Ramsar Sites (1.5 million hectares; Scott 1995; Ramsar Bureau, 2008). All these areas together provide the core for biodiversity conservation in Iran. However, in the long term these areas may not be sufficiently large to conserve all biodiversity within them and their protection and management should be harmonized with the land-use in adjacent areas.

At present, only protected areas assure reliable conservation of Iran's biodiversity. In the unprotected areas, biodiversity is diminishing rapidly: during the last 30 years, 1.2 million hectares (40%) of Iran’s deciduous-temperate forests have been converted to other land-use types (CBD, 2005). Rangelands and marginal farmlands are vulnerable to desertification, which is being exacerbated by soil erosion, over-grazing and over-exploitation of marginal farming areas. Coastal habitats and water resources are threatened by oil, industrial and agricultural pollution and over-fishing. In addition, large tracts of wetlands were devastated during the 8 years of Iraq–Iran war (1980–1988) and require restoration. At the species level, based on the Red List 2006, 96 species are internationally threatened on Iranian territory (19 mammals, 22 birds, 10 reptiles, 4 amphibians, 14 fishes, 8 cartilaginous fishes, 5 insects, and 14 cnidarians; IUCN 2008).

With more than 70 million people and 35% of the population being under 15 years and 3% over 65 years old, Iran has a young population. At present, population growth rate is still high at about 1.5% (INPS, 2006) and the population size is predicted to reach 100 million people by 2025 (EarthTrends, 2003). This population demands energy and the rate of energy consumption is growing very fast: compared to 1980 it has been increased by 198% in 2002. About 98.8% of the energy demand is covered by fossil fuels (EarthTrends, 2003).

2.2. EIA legislation and institutional framework for EIA

Environmental legislation in Iran started about 50 years ago by the Hunting Law in 1956 (Table 1). The Hunting Center was formed as an independent formation to regulate hunting permits. In 1963, special ecosystems, wildlife parks and protected areas were included in the Hunting Law. In 1976, the Hunting Center was promoted and transformed to the Hunting-Fishing Organization (HFO). This organization manages the research on wildlife, special ecosystems and protected areas; it has the duty to protect these areas and wildlife habitats. The Hunting-Fishing Control Organization is administrated by the Hunting-Fishing High Council (HFHC). In 1972, the HFO was renamed to Department of the Environment (DoE) and, at the same time, a general jurisdiction for environmental protection was enacted. The power of the DoE and its responsibilities grew steadily and now it is affiliated to the President's Office and is administered by the Environmental Protection High Council (EPHC). The EPHC and the DoE is chaired by the same specially appointed vice-president.

Based on the Environmental Protection and Enhancement Act (1974; Table 1), the DoE shall be responsible for the protection and enhancement of the environment, the prevention and control of any form of pollution or degradation leading to a disturbance in environmental balance, the declaration of ecologically critical areas, the regulation on any game and hunting activity (permits), promulgation of standards for quality of air, water, soil, noise and waste disposal as well as for conducting all matters related to environmental violation especially of wildlife and aquatic biota in in-land waters (DoE, 2004). In addition, Article 50 of the constitution of the Islamic Republic of Iran declares the protection of the environment a public obligation and therefore "any economic and other activity, which results in pollution or irremediable destruction of the environment, is prohibited." Table 1 shows important relevant laws on environmental protection in Iran.

Since regulations on economical, cultural and societal development have been issued, the environmental protection system in Iran is experiencing a new face of legislation, which considers environmental issues in economical, cultural and societal development: in 1994, the Environmental Impact Assessment (EIA) in Iran was enabled by Note 82 of the law for the second Five-year Economical, Cultural and Societal Development plan (APO, 1994), amended by Article 105 of the third Development Plan (APO, 1998). This note was confirmed by the 4th National Development Plan in Article 71. The Note 82 of the law for the second Five-year Economical, Cultural and Societal Development plan states (APO, 1994): *"EIA studies should be done based on the EPHC* (*Environmental Protection High Council) code of Practice (will be prepared by DoE and ratified by EPHC), for any large projects before implementation while the feasibility and site-selection studies are being done."*

Environmental Impact Assessment was approved by the EPHC through Decree 138 on 12 April 1994. The competent body for conducting EIAs (the EIA Bureau) as defined in Decree 138 is the DoE, under the authority of the EPHC. The EPHC itself is composed of the 1) director of DoE, 2) five government ministries, 3) the director of the Administration and Planning Organization (APO), 4) the director of Standards and Industrial Researches and 5) four senior academics and advisors to the government. The responsibility of supervising the EIAs falls within the mandate of the Deputy Head for the Human Environment, who is assisted by four bureaus (Bureau of EIA, Bureau of Air pollution, Bureau of Water and Soil pollution, and Bureau of Laboratories) each headed by a director general. The EIA Bureau is part of the Deputy Head for the Human Environment. The EIA Committee consists of a member of the EIA Bureau, a member of the DoE, members of the APO, a member of the environmental NGOs, and a representative of the proponents of a development project (usually a company consultant). This EIA Committee is responsible for decision-making based on the EIA reports prepared by the proponents (see sections on decision making below).

2.3. EIA procedures in Iran

The main steps in the Iranian EIA system are shown in Figures 1A (modified after DoE, 2003) and 1B (modified after DoE, 2006). The EIA Bureau follows this flowchart, screens the projects, controls the quality of the EIA reports and makes the decision whether a project is environmentally acceptable to be implemented. Based on Note 82, EIAs must be done in the feasibility stage of a project to identify possible negative and positive impacts before implementation. In addition, an EIA needs to prepare the measures to mitigate negative impacts.

After the submission of every development proposal by a proponent to the responsible DoE provincial office, the office determines if it is necessary that an EIA is conducted according to Table 2. In Decree 138, 1994, the EPHC initially prepared a list of seven major project types, which require an EIA. Since 1994, this list has been elongated and by 2006 included 51 project types subjected to EIA (Table 2; DoE, 2006). If a provincial office has identified the need to do an EIA, the proponent has to prepare a preliminary EIA report. Even if no EIA is necessary, every project proponent must comply with “Environmental rules and standards” (DoE, 2003).

The preliminary EIA report will be evaluated by the EIA Bureau within 20 days (Figure 1A and 1B), which then decides whether a full EIA is needed. In Decree 138, 1994, the DoE ratified the Guideline of Environmental Impacts Assessment (DoE, 2004) that is also known as Code of Practice (DoE, 2004). It contains the most important framework for the EIA system in Iran, especially a ‘*Guide to the preparation of a summary of a plan’* and ‘*Guide to the preparation of the preliminary EIA report*’ for proponents.

For a full EIA, proponents should consider the whole project process and activities as well as all environmental factors. Usually, private or company consultants are performing an EIA and prepare the report. Proponents send the full Environmental Impact Statement (EIS) to the EIA Bureau where, after 90 days of reviewing, the EIA Committee is in charge to decide about the project (see section on decision making below). If the EIS needs some revision, the proponent has to do this. The EIA Committee has also the right to reject a proposal, but in practice, proposals are approved after some revision.

3. Evaluation of the EIA procedures in Iran

3.1. Evaluation Criteria

To date, there is no reliable quantification of the effectiveness of EIA worldwide, so the only possibility is to evaluate it subjectively (Wood, 2003a). Wood (2003a) developed such criteria by asking questions about each stage of an EIA system (Table 3). By finding the answer to these questions, a simple evaluation of the effectiveness of an EIA system can be carried out. Here we do this for the Iranian EIA system. The answers to the questions are based on the corresponding laws and guidelines presented in the previous sections.

3.2. Evaluation of the EIA system

3.2.1. Legal basis

In Iran, the first and most important concern about EIA is that there is no specific and independent law regularizing the EIA process. EIAs are subject to a Decree of Law on a Five-year Economical, Cultural and Societal Development plan (ECSD). The law on ECSD is structure and direction of the development for each 5-year period. It should be ratified by the parliament before each next 5-year period starts. So, the content of the law depends on the situation to date and there is no guarantee that EIA is always a part of it. In Iran, EIA is lacking a legal definition and even the contents of EIA are not clearly defined (METAP, 2002). In addition, there is no legal provision for enforcing commitments made in EIA studies and there are no clear sanctions and penalties for any deficiencies by developers (METAP, 2002). By-passing of the EIA requirements is another problem that the EIA system in Iran is suffering (Ghodoosi et al., 2006). Absence of efficient and structured linkage between developmental organizations resulted in parallel work and even sometimes abandonment the responsibilities. For example, some duplication of efforts and potential conflicts is happening between different authorities with environmental responsibilities i.e. the Department of Environment and the Ministry of Jahad and Agriculture. In general, there is lack of clarity in the legal provision at different stages, a problem that will be discussed in more detail later on.

3.2.2. Coverage

The objective of an EIA is to ensure that prior to implementation all the environmental impacts of significant actions are assessed (Wood, 2003a). Projects in Iran that may have significant impacts on the environment, e.g. power plants, steel melting manufacturers, dams as well as oil and gas pipelines, require an EIA (Table 2). The coverage of the EIA in Iran is mainly explained in Article 7 and Article 10 of the 'Code of practice' by EPHC issued on 23rd Dec. 1997 (DoE, 2003).

In Article 7, it is mentioned that an EIA should be prepared for two phases of the projects: the construction period and the operation period. In Article 10, it is mentioned that EIA should cover impacts on physical, biological, socio-economic and cultural variables, as well as impacts on other developmental projects, as follows:

a. Impacts on the physical environment

1) Impacts on land such as changes in morphology

2) Impacts on water such as changes in water quality and quantity

3) Impacts on climate, air and sound (climate change, changes in precipitation and air quality, acoustic pollution)

4) Secondary impacts on the interactions of soil, water and air

b. Impacts on the biological environment

1) Impacts on plant species

2) Impacts on animal species

3) Impacts on habitats, landscapes and bird migration

c. Impacts on socio-economic and cultural environment

1) Impacts on individual and public health

2) Impacts on social environment such as employment, housing, education

3) Impacts on cultural environment such as religion, cultural beliefs and heritage

d. Impacts on other developmental plans:

1) Impacts on the other agricultural, industrial and service developmental plans in the region

2) Impacts on the regional land-use planning

As it is shown in article 10, EIA concerns both the natural and anthropogenic environment. However, indirect and cumulative impacts are not explicitly considered although there is a hint in part (d) of Article 10. In part (d) the investigation of the likely impacts of a given project on other existing projects is required but the impact types are not clarified. Hence, practitioners often consider the socio-economic impacts only.

3.2.3. Alternatives

Consideration of alternative project plans in the Iranian EIA system is obligatory by Note 10 of the '*Guide to the preparation of a summary of a plan*'. It is noted that: "Proposed sites for the project, location choices and the reasons of selecting the proposed place or places are necessary." In note 2-6 of '*Guide to the preparation of the preliminary EIA report,*' it has also been mentioned that technical and spatial alternatives for the project should be included in the EIA report.

In an EIA process, a "no-action" or "no-project" alternative should routinely be included in an impact assessment (WB, 1996). In Iran, projects which are funded by the World Bank usually have this consideration of a no-action alternative, but for other projects, based on the legal basis, considering this alternative is not obligatory. It is because of economical and technical problems that alternatives are often not considered (see also chapter 5).

3.2.4. Screening

In Iran, to date 51 project types are subject to EIA (Table 2). For screening of projects that are likely to have an environmental impact (see Table 2), proponents should announce the proposal to the responsible provincial office of DoE. If the project falls into the list in Table 2, then the proponent will be asked to prepare a preliminary EIA report (See Fig 1A and 1B). Then, the preliminary EIA report will be reviewed by the EIA bureau in the DoE to check whether a full EIA is needed or not.

Screening in Iran is based on a list of actions and thresholds prepared by the DoE (Table 2). A preliminary EIA is necessary for all projects similar to the ones listed in Table

2. However, for some projects additional full EIA will be required. Hence, a splitting of that list into two lists, which show what kind of projects require only a primary EIA and which ones a full EIA (as it is done in World Bank' category A and B; World Bank, 1991) will help to have a better definition of primary and full EIA and reduce financial costs and time requirements.

3.2.5 Scoping

Scoping is the process of deciding which impacts are the significant ones among all project's impacts and from all the project's alternatives should be addressed (Glasson et al., 2005). The scoping stage is the key stage in EIA and its effectiveness guarantees the quality of the assessment and EIA report.

In Iran, practitioners are using four methods for EIA: a) Leopold Matrix (Canter, 1996), b) Degradation Model (Makhdoum, 2002), c) Checklist and d) Overlay. Leopold Matrix is the most commonly used method in EIA in the world and in Iran as well. However, often weighting of impacts is not based on the strict analysis of data and rather is speculative. In Iran, by now for more than 17 project types EIA guidelines have been prepared by DoE and UNDP. The booklets are accessible at the DoE for the public, private consultants, developers and academics. These booklets can help developers for better understanding of how their activities will influence environmental factors. The booklets are prepared based on the most frequent approach of Leopold Matrix (Canter, 1996). In the Leopold matrix, columns are representing the various activities of the project, and rows represent the various environmental factors to be considered.

In Iran like in many other developing countries, at the scoping stage often pollution-related impacts are considered, rather than addressing the full range of potential environmental impacts from a proposed development (George, 2000a). In addition, in developing countries, practitioners are often under pressure not to hinder development of economically vital projects by undertaking of significant environmental impacts into assessment (Bektashi, 2002).

3.2.6. EIA report content

The detailed content of an EIA report has been defined in the 'Code of Practice 1997' by the '*Guide to the preparation of a summary of a plan*' and the '*Guide to the preparation of the* *preliminary EIA report*'. The problems of this stage are coming from the previous stages; the content of preliminary and full EIA reports is not differentiated. Another problem is that the likely impacts of the decommissioning phase of projects are not considered compulsory to be assessed and reported.

3.2.7. EIA report review

EIA report content and review have strong and direct influence on decision making. Hence, a strong and reasonable content as well as a precise review will lead to a right decision.

After submitting the EIA report to the provincial office, this will have a primary review whether a full EIA is needed or not. Then, the report will be passed to the DoE in Tehran for an in-depth review and for decision-making (Fig. 1B). Only at this stage consultation formally takes place and mostly academics will help the EIA bureau to review the reports. However, there is no opportunity for the public to take part in reviewing the EIA reports. In addition, often the EIA Bureau is still suffering from a lack of well-trained and experienced staff (METAP, 2002).

3.2.8. Decision making

The 'Code of practice' in the '*Guide for supervision on EIA reports*' describes how to make a decision about the proposed projects. It mentions that "controlling on effectiveness of the projects implementation" is the immediate purpose of the decision-making process. EIA committee members are: (1) Head of Deputy of Human Environment (committee president), (2) Head of EIA Bureau (committee Secretary), (3) Related expert from EIA Bureau, (4) Representative of Deputy for Natural Environment and biodiversity, (5) Academic expert, (6) Representative of NGOs, (7) Head of related provincial office, (8) Representative of Planning and Management Organization and (9) Representative of proponent. Decisions are reached by voting by members (1), (4), (5), (7) and (8); other committee members, e.g. (6), have no voting rights. The EIA committee has the right to refuse the proposal, verify it or verify it subject to revision. The decision will not be made public.

3.2.9. Impact monitoring and Mitigation measures

The positive decision of the EIA committee is often thought as an acceptance for a particular project and assumed that it is the end of environmental concerns. However, as it is noted by part 9-2 of the '*Guide to the preparation of the preliminary EIA report*', proponents are required to suggest the proper measures to avoid, minimize or remedy the adverse impacts (mitigation measures) and monitoring actions for controlling the condition of the project during the operation. In addition, in part 9-1, proponents are required to propose the specific measures to reduce impacts on physical, biological, socio-economical and cultural variables. In this case, there are some shortcomings: 1) proposed mitigation measures are sometimes speculative and irrelevant (Ghodoosi et al., 2006): 2) there is no legal enforcement to guarantee the implementation of mitigation measures and monitoring actions in the operation phase; 3) inspection and supervision on proponent activities in the operational phase are not the duty of the EIA Bureau or the DoE, but are duties of APO (Ghoddoussi 2006; for a list of abbreviations see Appendix 1). 4) for the proponents cost-effectiveness is prior to the environmental measures mentioned in the mitigation plan (Canter, 1996).

3.2.10. Consultation and public participation

The objective of consultation and public participation is to improve the quality of environmental decisions (Wood, 2003a) and even public pressure could have a major influence on the EIA effectiveness (Marrison-Saunders, 2001). In Iran, recently more than 428 NGOs have been active in environmental issues within the last 12 years (DoE, 2005). A representative of environmental NGOs, on behalf of the public, participates in the EIA committee for decision-making (Code of practice). That is the only legal participation of the public although the representative of the NGO has no strong role in decision-making (see decision making-section). In 2005, the HPHC (for a list of abbreviations see Appendix 1) ratified the first provision on public participation in the EIA process. Now, proponents have to advertise the project in local newspapers to involve public feedback in the assessment. However, the public tends to have no strong inclination to take part in this process. It might be because: a) the public does not have enough environmental knowledge; b) they do not see why they should be involved or c) they assume that their opinion will not influence the decisions.

3.2.11. System monitoring

We believe that the monitoring of the whole EIA system in Iran is vital to overcome problems and limitations mentioned in the last sections. For instance, unclear legal basis, vague EIA guideline, very long review process and lack of inspection on the monitoring process were stated as the main reasons to carry out a system monitoring of the EIA process in Iran (Ghodoosi et al., 2006).

3.2.12. Cost and Benefits

The cost associated with EIA varies between projects and range from 0.1% to 1% of the whole project costs internationally (Glasson et al., 1999). In Iran, the costs of an EIA are usually varying between 5–20% of the total costs of the feasibility studied phase. In addition, the time requirement of assessment causes delays. Also, the decision-making process takes a long time and often exceeds the expected costs.

3.2.13. Strategic environmental assessment (SEA)

A strategic environmental assessment (SEA) is a systematic process for evaluating the environmental consequences of a proposed policy, plan or program initiative to ensure that they are fully included and appropriately addressed at the earliest appropriate stage of decision-making on par with economic and social considerations (Sadler, 1996).

In Iran, by 2004 the UNDP (for a list of abbreviations see Appendix 1) agreed to a project with the DoE entitled “Sustainable Development Strategy and Strategic Environmental Assessment: enabling activities and capacity-building.” The project aims to take Iran a step forward from EIA of individual projects towards the incorporation of sustainable development concerns and criteria in decision-making of policies, plans and programs. A core group of professionals from various national stakeholders (ministries, NGOs, academics) has been established and trained in SEA to work on the following outputs: capacity building and training; needs assessment practices in selected sectors (energy, transportation, water); national regulatory framework for undertaking SEAs; SEA technical guidelines; facilitating stakeholders access to knowledge and experience on SEA; creating an ensuring sustainable development (UNDP, 2004).

4. Conclusion and recommendations

We showed that considerable progress has been made in the past 14 years concerning the implementation of an EIA system in Iran and the recent initiative to use environmental assessments also in earlier stages of policy formulations (SEA). However, there are still some problems and shortcomings in the procedure at the different stages of an EIA, from baseline studies to monitoring requirements and more. Obviously, similar problems exist in other countries, and EIA is still far from perfect globally (Ahammed, 2006).

One problem in the EIA system in Iran is that for some of the stages of an EIA there is no published documentation available that would guide proponents of projects and evaluation authorities. Nevertheless, for most stages of the Iranian EIA system, a legal basis is available that must be followed. This legal basis could be used to develop guidelines and documentations for key issues of the EIA process such as the report review, public participation and consultation, system monitoring and cost and benefits analysis. For this, it would be useful if the existing legal framework could be combined into a new, independent law. The law should have clear definitions of environmental impacts of development projects and of the aim and nature of an EIA. The EIA process should be clearly structured and the role of stakeholders, proponents, public and all other organizations involved should be explained. Furthermore, the penalties applicable in case of violating the law should be included in the law. The EIA Bureau or DoE should be required to publish decisions concerning all EIA carried out for the different development projects.

Poor quality of EISs is one of the great concerns of all experts involved in EIA. Poor quality can be due to inaccurate data from baseline studies or unsuitable data analysis and interpretation. In addition, unrealistic and therefore non-applicable mitigation measures can contribute to inefficiency of EISs. In this context, it would be highly desirable if an environmental information database with free access for developers, consultants and the public could be created. Also, if the EIA Bureau could devote more staff and technical capacity to EIA, the quality of EISs could be improved. The strong emphasis on pollution control in previous EISs has tended to limit the attention given to other aspects of impact monitoring. Providing a legal basis and guidelines for a more comprehensive monitoring would be a very important next step.

The public in Iran has become more environmentally knowledgeable and concerned over the past 12 years. Environmental NGOs are becoming more active. However, public participation in the EIA process is still limited and unsatisfactory. First, clarifying the public involvement in EIA processes is necessary. Second, the public should be made aware of ecological and socio-economical impacts of developmental projects. Third, environmental NGOs should be able to contribute more effectively to EIA processes. Forth, all decisions made by EIA Committees about projects should be published to convince the public that their involvement is taken seriously and that they have an influence on decision making. This will reduce bias in EIA and thus poor decision-making (Wang Y., 2003).

Finally, to strengthen the scientific basis of EIA in Iran, universities will have to play an important role. Strengthening the understanding of environmental ethics and of modern conservation measures among students, teachers, developers, consultants, NGOs and the public will be necessary to make them aware of the inherent values of the environment and the threats posed by badly designed development projects.

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Table 1 The history of main environmental laws in Iran (translated from the Persian version of "Laws and Rules for Environmental Conservation in Iran – Volume 1"; DoE, 2004).

Title of the law	**Year of Legislation**
Hunting Law	1956
The Plant Protection Act	1967
Law on the Protection of Forest and Rangelands	1967
Law on Hunting and Fishing	1967
Environmental Protection and Enhancement Act	1974
Law for Endangered Species of Wild Fauna and Flora	1974
Law for Protection of the Nature Parks, Protected Areas and Sensitive Areas	1975
Land Acquisition Law	1980
Law for Proper Use of Water Resources	1982
Law for Protecting Environment against Water Pollution	1984
Law for Protecting Environment against Natural Environmental Damages	1991
Law on Five-year Economical, Cultural and Societal Development plan (1^{st} National Development Plan)	1989
Law on Five-year Economical, Cultural and Societal Development plan (2^{nd} National Development Plan)	1994
Law on Air Pollution Control	1995
Law on Five-year Economical, Cultural and Societal Development plan (3^{rd} National Development Plan)	1998
Law on Five-year Economical, Cultural and Societal Development plan (4^{th} National Development Plan)	2004
Waste Disposal Act	2004

Table 2 List of projects that require an EIA in the Iranian EIA system (translated from Persian version on the DoE website under “DoE, List of projects subjected to EIA in Iran, 2006” at: http://www.irandoe.org/doeportal/eia/).

No.	Project type	Listed since
1	Petrochemical plants in general	23 December 1997
2	Refinery plants in general	23 December 1997
3	Power plants with a capacity larger than 100 Mega Watt	23 December 1997
4	Steel-melting plants	23 December 1997
5	Dams with height more than 15 m or related structures that have an area larger than 40 ha or water reservoir that has an area larger than 400 ha Note: a) tailing dams in general, b) man-made lakes with more than 400ha, c) fishery lakes (aquaculture) with an area of less than 400 ha (by permission of ministry of Jahad and Agriculture and DoE), d) irrigation systems with an area larger than 1000 ha	23 December 1997
6	Industrial parks with an area larger than 100 ha	23 December 1997
7	Airports with more than 2-km long runways (band length)	23 December 1997
8	Agro-industry with areas larger than 5000ha	24 August 1999
6	Large slaughter houses	23 December 1999
10	Domestic solid waste landfills for cities having population of more than 200,000 and for new cities	23 December 1999
11	Composting centers	23 December 1999
12	Oil and gas pipelines	29 November 2000
13	Oil exploitation in sea or in lakes	29 November 2000
14	Oil reservoirs	29 November 2000
15	Large forestry projects	29 November 2000
16	Highways and freeways	17 October 2001
17	Large railway projects	17 October 2001
18	Tourism projects	11 June 2002
19	Coastal development projects within a range of 1 km from the coast	17 March 2004
20	Industrial complexes and units with an area larger than 5000 m^2	17 March 2004
21	Industrial and related activities, e.g. exhibition halls with an area larger than 10000 m^2	17 March 2004
22	Chemical and hazardous materials storages with an area larger than 5000 m^2	17 March 2004
23	Construction campus with an area larger than 10000 m^2	17 March 2004
24	Fuel storage with capacity more than 1 million liter	17 March 2004
25	Bus and trucks terminals with an area larger than 2000 m^2	17 March 2004
26	Large ranches with an area larger than 5 ha	17 March 2004
27	Marine ports, for fishery or oil and gas and dredging (marine construction in general)	17 March 2004

28	Wastewater collecting network and treatment center in city scale	17 March 2004
29	Large water treatment in city scale(with capacity more than 5000 m^3/day	17 March 2004
30	Landfills, e.g. collecting and disposal in city scale	17 March 2004
31	Military centers with more than 5000 m^2	17 March 2004
32	Tourism complexes with an area larger than 10000 m^2	17 March 2004
33	Film making centers with an area larger than 5000 m^2	17 March 2004
34	Recreational, educational, research and sport centers with an area larger than 10000 m^2	17 March 2004
35	Copper extraction with a capacity of more than 1 million tons/year	17 March 2004
36	Iron extraction with a capacity of more than 600 thousands tons/year	17 March 2004
37	Gold extraction in general	17 March 2004
38	Lead and zinc extraction with a capacity of more than 100,000 tons/year	17 March 2004
39	Coal extraction with a capacity of more than 80,000 tons/year	17 March 2004
40	Salt extraction from water with an area larger than 400 ha	17 March 2004
41	Cement plants in general	4 May 2005
42	Sugar plants in general	4 May 2005
43	Gypsum-plaster and limestone manufactories	4 May 2005
44	Drug and cosmetic industries in general	4 May 2005
45	Large units supplying automotive pieces	4 May 2005
46	Used-motor-oil recycling stations	4 May 2005
47	Oil/gas fields development projects with more than 10 wells	4 May 2005
48	Residential places(hotels, motel, etc.) with a capacity of more than 120 person or an area larger than 2ha	5 October 2005
49	Camping site with more than 150 tents or an area larger than 5 ha	5 October 2005
50	Recreational and tourist complexes with an area larger than 5 ha	5 October 2005
51	Coastal construction (mineral water baths) in general	5 October 2005

Table 3 Evaluation of the 14 stages listed in Table 3 for the EIA system in Iran (Source: Wood C. 2003).

Stage No.	Evaluation Criterion
1	**Legal basis:** Is the EIA system based on clear and specific legal provisions?
2	**Coverage:** Must the relevant environmental impacts of all significant actions be assessed?
3	**Alternatives:** Must evidence of the consideration, by the proponent, of the environmental impacts of reasonable alternative actions be demonstrated in the EIA process?
4	**Screening:** Must screening of actions for environmental significance take place?
5	**Scoping:** Must scoping of the environmental impacts of actions take place and specific guidelines be Produced?
6	**EIA report contents:** Must EIA reports meet prescribed content requirements and do checks to prevent the release of inadequate EIA reports exist?
7	**EIA report review:** Must EIA reports be publicly reviewed and the proponent respond to the points raised?
8	**Decision-making:** Must the findings of the EIA report and the review be a central determinant of the decision on the action?
9	**Impact monitoring:** Must monitoring of action impacts be undertaken and is it linked to the earlier stages of the EIA process?
10	**Mitigation measures:** Must the mitigation of action impacts be considered at the various stages of the EIA process?
11	**Consultation and public participation:** Must consultation and participation take place prior to, and following, EIA report publication?
12	**System monitoring:** Must the EIA system be monitored and, if necessary, be amended to incorporate feedbacks from experience?
13	**Cost and benefits:** Are the financial costs and time requirements of the EIA system acceptable to those involved and are they believed to be outweighed by discernible environmental benefits?
14	**SEA:** Does the EIA system apply to significant programs, plans and policies, as well as to projects?

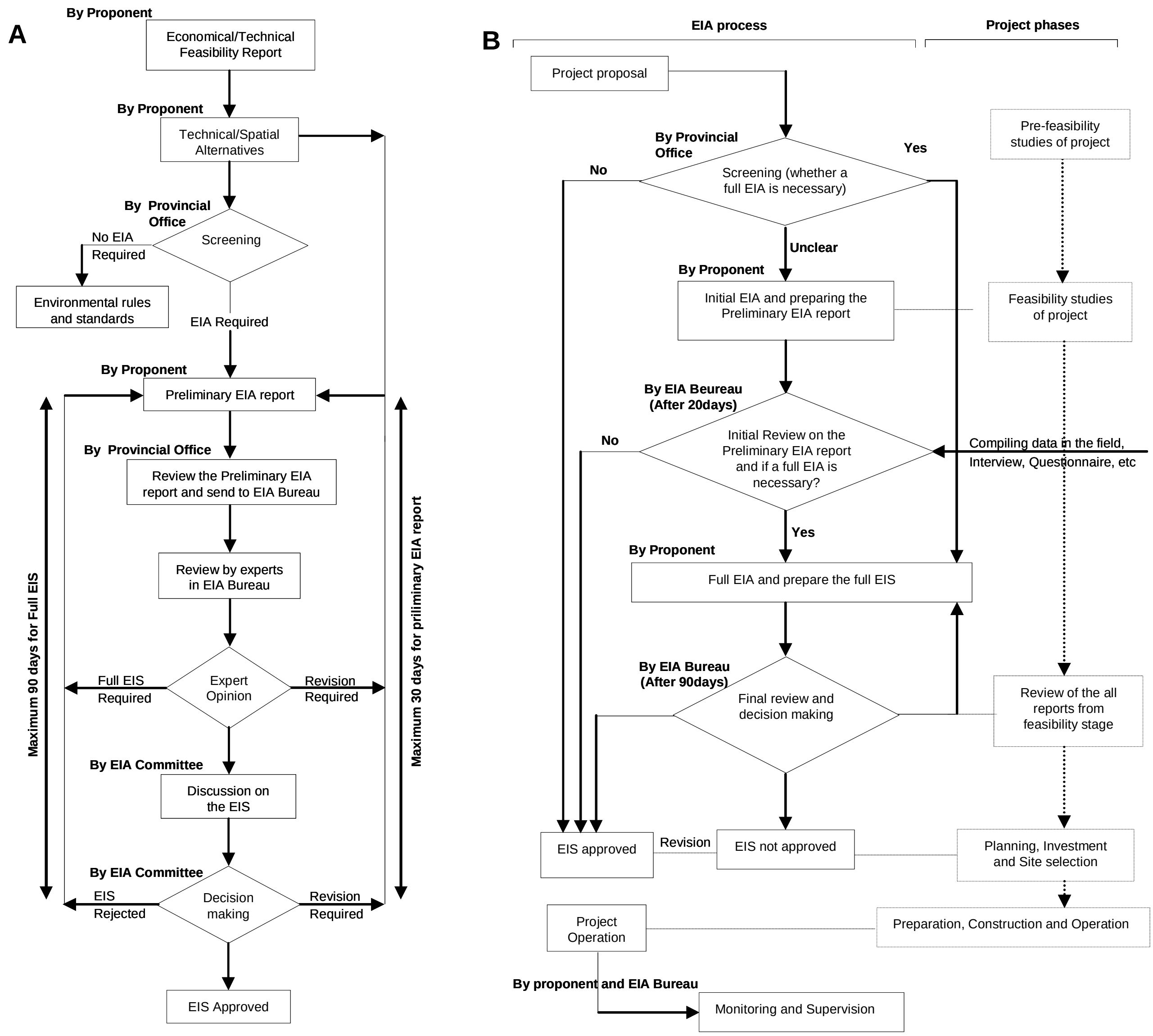


Figure 1 The EIA procedure in Iran. Figure 1A (left) shows the old version of the EIA procedure (translated from the Persian version of "Environmental Rules and Standards in Iran"; DoE, 2003). Figure 1B shows the new version of the EIA procedure, translated from the DoE website, 2006, EIA procedure, at: DoE, http://www.irandoe.org/doeportal/eia/). In both figures, □ indicates information and ◊ indicates decision-making; Solid lines (—) show the main process and dashed lines (…) show parallel phases of a development project.

APPENDIX

A1: Abbreviation used in this Chapter.

Abbreviation	Title
APO	Administration and Planning Organization
CBD	Convention on Biological Diversity
DoE	Department of Environment
ECSD	Economical, Cultural and Societal Development
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPHC	Environmental Protection High Council
FAO	Food and Agriculture Organization
HFO	Hunting-Fishing Organization
HFHC	Hunting-Fishing High Council
INPS	Iranian National Portal of Statistics
IUCN	International Union for Conservation of Nature
MENA	Middle East and North Africa
METAP	(Mediterranean Environmental Technical Assistance Program
NGOs	Non-governmental organizations
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
SEA	Strategic Environmental Assessment
WB	World Bank
WWF	World Wildlife Fund

5

Effectiveness of Environmental Impact Statements in Iran 1996–2006

Hossein Moradi, Jasmin Joshi and Bernhard Schmid

ABSTRACT

Environmental Impacts Assessment (EIA) was formally developed as a decision tool about 40 years ago. Middle Eastern countries only started in the 1990s with the implementation of EIAs. A number of studies assessed the legal basis of EIAs after several years of experience. However, the quality of Environmental Impact Statements (EISs) of projects has rarely been assessed. This quality plays a key role in the decision making process of development projects and can be used as an indicator of the effectiveness of an EIA system. In this study, we evaluated the effectiveness of 96 Iranian EISs prepared from 1996–2006 using evaluation checklists to calculate the proportion of possible elements present in an EIS. The projects for which the statements were prepared could be classified into 17 types. We assessed the methodology used in the 96 EIS and the three most important sections of the EIS, i.e. scoping, mitigation plan, and monitoring plan.

We found that the methodological approaches in Iranian IES were often not optimal; for example, original data were rarely collected. According to our analysis, developmental projects were most likely to affect grassland ecosystems followed by rivers and mountains, but even rare ecosystems such as mangroves and coral reefs were sometimes at risk. However, in most Iranian EISs, biological impacts were not sufficiently assessed and only the EISs of one project type (i.e. *Water transferring*) rated biological impacts higher than physical impacts. Biological variables were often neglected in monitoring plans even in EISs of projects with high risks of destruction of ecosystems. In addition, mitigation and monitoring plans in Iranian EISs were often not prepared as well-structured sections.

Overall, the investigated EISs had a low effectiveness. However, we found that there is a tendency for improvement. The number of identified physical impacts and suggested mitigation measures and monitoring actions increased significantly from 1996–2006. Unfortunately no such improvement can yet be seen for biological impact identification. We conclude that impacts of development projects on biological variables and ecosystem functions should be taken into account at all stages of EIAs and in all sections of EISs in Iran.

Key words: Environmental impact assessment, evaluation checklist, Bayesian network, Iran

1. INTRODUCTION

Environmental Impacts Assessment (EIA) was formally developed as a decision tool in United States in 1969 (Glasson et al., 2005). It is about 40 years that EIA has become an instrument to consider the adverse impacts of large developmental projects on the environment (Brismar 2004). Up to now, more than half of the countries in the world have implemented EIAs (Mandelik et al., 2005; Glosson et al., 2005; Androulidakis and Karakassis 2006). Generally, Middle Eastern countries were quite late and only started in the 1990s with implementation; they still do not have EIA fully legislated (El-Fadl and El-Fadel 2004). It was in 1994 that the provisions for EIA were adopted in Iran (DoE 2004).

A key question about the implementation of EIA globally is whether translated “Western style” EIA can be successful in non-Western countries (El-Fadl and El-Fadel 2004). Even if EIA systems cannot be identically translated into a non-Western context, they can at least increase the attention of scientists, policy makers and the public for potentially negative social, economic and environmental impacts of major developmental projects. Even if principles are similar in all the EIA systems, they may vary in details of procedures and practical implementation (Glosson 2000). This is because ecological as well as socio-economic and cultural conditions differ among countries.

Several recent studies focused on the legal basis of EIA in developed (Goncalves 2002; Glasson and Bellanger 2003; Canelas et al. 2005) or developing countries (Wood and Coppel 1999; Glasson and Salvador 2000; Appiah-Opoku 2001; Ahmad and Wood 2002; Bektashi and Cherp 2002; Ahammed and Harvey 2004; Briffett et al. 2004; Ogunba 2004; Coskun 2005; Paliwal 2006). Other studies evaluated the quality of Environmental Impact Statements (EISs) for a particular project type (Bojorquez-Tapia and Garcia 1998; Brismar 2004; Pinho et al. 2007; Tzoumis 2007) or for multiple project types (Kim 1991; Barker and Wood 1999; Canelas et al. 2005). Some studies assessed the level of documentation of biodiversity-relevant impacts and explored the deficiencies in their assessment (Thompson and Treweek 1997; Treweek and Thompson 1997; Atkinson et al.2000; Slootweg and Kolhoff 2003; Mandelik et al. 2005; Tinker et al. 2005). In any EIA system, the quality of EISs plays a vital role in the decision making of proposed projects and can be used as an indicator of the effectiveness of EIAs (Lee et al. 1994; Thompson and Treweek 1997; Barker and Wood 1999; Morrison-Saunders et al. 2001).

Assessing the likely impacts of projects on biodiversity and other ecological variables should be an essential part of an EIA (CBD, 2001, Slootweg and Kolhoff 2003). Article 14 of the Convention on Biological Diversity (CBD) requires parties to apply EIAs to projects that potentially negatively impact biodiversity (CBD, 2001). There are a number of studies that identified the level of documentation of biodiversity as well as explored the deficiencies in biodiversity impact assessment (Thompson and Treweek 1997; Treweek and Thompson 1997; Atkinson et al.2000; Slootweg and Kolhoff 2003; Tinker et al. 2005).

Recently, it has been suggested that a systematic review of the EIA system in Iran should be carried out (Ghodoosi et al. 2006). In an earlier chapter, we evaluated the legislations and guidelines of EIA in Iran to present shortcomings of the system (Moradi et al., chapter 4). In the present chapter, we examined how practitioners in Iran prepared different sections of the EISs for 17 different project types. We carried out a quality assessment of the methodology used for EIAs in Iran, considering each of the three main sections of EISs: *Scoping*, *Mitigation plan*, and *Monitoring plan*. We analyzed how effectively the environmental impacts of the studied projects had been identified and evaluated (scoping). We also examined whether mitigation plans as well as monitoring plans were structured by relevant, useful and applicable suggestions. Finally, we compared the strengths with the weaknesses of the EISs for different project types. We studied a total of 96 EISs from Iran. For each EIS, we extracted a large number of characteristics and used these as variables in the subsequent analysis. To evaluate the effectiveness of the different EISs we used Bayesian network analysis. Using sensitivity analysis for the Bayesian network, we checked how effectiveness of the three main sections and their subsections in EISs influenced the overall effectiveness of the EISs.

2. MATERIALS AND METHODS

2.1. Sampling method

A systematic review of 96 collected EISs from Iran was conducted to evaluate the quality of the EIA system in Iran from 1996–2006. The different EISs were consulted in the archive of the EIA Bureau of the Department of the Environment (DoE) of Iran and in bureaus of environmental consulting firms.

In Iran, EIA became obligatory for large projects in 1994 (see Chapter 4). At the time of data collecting (2006), 337 EISs were archived in the EIA Bureau. The number of EISs per year increased considerably after 2000 (Fig. 1). Dam constructions, industrial complexes, power plants, gas and oil pipelines, and steel melting plants were the most frequent development projects (Table 1b). These projects were mostly carried out for Khuzestan and Hormozgan, followed by Tehran, Mazandaran and Khorasan provinces (Table 1a).

2.2. Evaluation checklists

We classified the collected statements in 17 classes which reflect major project types in Iran, e.g. *Oil and gas pipelines and reservoirs, Industrial complexes, Steel melting plants, Dam construction* and *Hydro-power plants*, *Power plants*, and *Oil and gas refineries* and *Oilfield developments* (Table 1b). An EIS consists of a non-technical summary, a description of the project, a description of the environment, the identification and evaluation of the potential impacts (scoping), measures to avoid, minimize or remedy the adverse impacts (mitigation measures) and monitoring actions for controlling the condition of the project during the operation. First, we examined the following: 1) how data, which were used in each EIA had been collected (i.e. whether data were collected based on *New surveys*, *Maps*, *Aerial photographs*, *Satellite images* or *Questionnaires* or several of these); 2) which method had been used for impact assessment (*Checklists*, *Leopold matrices*, *Overlays* or *Quantitative approaches*); 3) and whether different project alternatives or a 'No-project alternative' had been considered.

Secondly, we made project-type specific evaluation checklists for the three main sections of the EISs, i.e. *Scoping*, *Mitigation plan*, and *Monitoring plan*. We used published guidelines and books (DoE and UNDP 2001; European Commission 2001a; European Commission 2001b; USDOE 1997; Glasson et al. 2005; Treweek 1999; Atkinson et al. 2000), which present potential environmental impacts, mitigation measures and monitoring actions for different project types, to compile these checklists. The checklists contained all the potential environmental impacts, mitigation measures and monitoring actions, which were expected to be considered in the EIA process. After compiling the checklists, we modified them according to the type of activities and to the affected environment. Our basic data were the number of elements considered in an EIS out of the number of elements listed in the checklists. In the following, we describe the three main sections of EISs, which we analyzed in this study.

2.2.1. Scoping

Scoping is the process of deciding, which impacts are the significant ones among all the potential impacts of a project and its alternatives (Glasson et al. 2005). We studied the effectiveness of scoping sections for both construction and operation phases of the projects in our sample. Three processes can be distinguished in scoping: *Impacts origin, Impacts identification* and *Impacts evaluation*.

For *Impacts origin,* we checked whether indirect or cumulative impacts had been assessed.

For *Impacts identification*, the checklist was divided into two major classes of physical or biological impacts. Physical impacts were further classified into *Habitat-scale impacts* (e.g. physical alteration, pollution, disturbance, habitat damage, habitat loss) and *Landscape-scale impacts* (e.g. habitat insularization, landscape change). Biological impacts were further classified into *Biological alteration*, *Wildlife mortality* and *Ecosystem functions*.

For *Impacts evaluation,* we checked whether the following criteria were evaluated: *Impacts nature* (positive or negative), *Evaluating dimensions* (magnitude, importance and certainty), *Spatial / temporal dimensions* (extent, duration, and frequency), *Reversibility,* and *Avoidability*.

If one or more than one of the criteria above were used in the evaluation, we called that impact ‘evaluated’. We called an impact ‘identified’ if it was mentioned or evaluated in the EIS. Only the identified impacts were included in the subsequent analysis of impacts.

2.2.2. Mitigation plan

A mitigation plan is a tool in order to avoid, reduce and, if possible, remedy significant adverse impacts (European Commission 1997; Glasson et al. 2005) and to strengthen useful impacts. We classified mitigation measures into the five classes: *Avoidance, Reduction / moderation / minimization, Repair / reinstatement / restoration, Rescue / relocation / translocation,* and *Compensation* (Treweek 1999).

2.2.3. Monitoring plan

An environmental monitoring plan is suggesting monitoring of environmental variables during the construction, operation or decommissioning phase of a project. Monitoring actions were divided into two main classes, *Physical* or *Biological*. Physical monitoring actions were further classified into actions related to air / noise, soil / sediment, surface water / underground water, waste disposal / waste treatment, and landscape variables. Biological monitoring actions were further classified into actions related to biodiversity (e.g. species density) and ecosystem (e.g. productivity) variables.

2.3. Variables considered in Iranian EISs

2.3.1. Biological variables potentially affected

We examined which of the major ecosystems such as grasslands, rivers, mountains, forests, lakes, intertidals, mangroves, estuaries and coral reefs were identified as potentially affected by the proposed projects. Over 97 protected sites, 9 natural reserves and 22 internationally protected wetlands are the core of a conservation network in Iran, which harbors 95 threatened species of the IUCN Red List (IUCN 2008). We examined whether the designated areas of this network and the species of the Red List were identified as potentially affected.

2.3.2. Changes in numbers of variables considered from 1996–2006

We analyzed the changes in the number of identified physical and biological impacts from 1996–2006 in Iranian EISs. The number of identified impacts in the scoping sections, the number of measures suggested in the mitigation plans, and the number of actions recommended in monitoring plans of the statements were calculated for each year. We tested the linear effect of “year” against the residual variation among “year”.

2.3.3. Differences in numbers of variables considered among project types

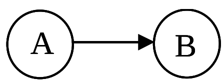
Methodology effectiveness was not analyzed because for different types of projects different kinds of methods might have been most suitable. However, we calculated the average number of identified impacts, suggested mitigation measures, and recommended monitoring actions for each project type.

2.4. Effectiveness of sections and overall effectiveness of EISs

We applied Bayesian network (Bn) analysis (Korb and Nicholson 2004; Kjaeulff and Madsen 2007) to assess the overall effectiveness of all 96 EISs and the effectiveness of their three main sections and their subsections. Bayesian networks are also known as belief networks, causal networks, probabilistic networks, or Markov random fields (Lee and Lee 2006; Castelletti and Soncini-Sessa 2007). A Bn consists of a set of variables, represented as *nodes*, which are connected by directed links, represented as *arrows* or *arcs* (Castelletti and Soncini-Sessa 2007). In general, a Bn is a Directed Acyclic Graph (DAG) representing causal relationships between variables by arrow connections and allowing evaluations of conditional dependences between variables (Lee and Lee 2006). We used the “Netica” software package (Norsys 2007) to carry out the Bn analysis. The software calculates *belief propagation* by employing Bayes’ Theorem (Huang and Darwiche 1996; Castelletti and Soncini-Sessa 2007). Bayes rule describes the relationship between the two conditional probabilities $p(A|B)$ and $p(B|A)$:

$$p(A|B) = \frac{p(B|A)\,p(A)}{p(B)}$$

Given a simple Bayesian network containing two nodes A and B, an arrow from A to B indicates that A *causes* B, so A and B are said to be *parent* and *child*, respectively (Bryan and Garrod 2006).



A child node may have more than one parent node. A node, which does not have any parents is called a *root node* and represents an input variable. Input nodes have unconditional probabilities. The root nodes feed the network by their input values. The output of the network arrives in a node that does not have any child. Such a node is called a *leaf node*. We entered the findings from the evaluation checklists into the tables of the input nodes. For this, first we calculated the percentage of elements considered in an EIS out of the number of elements listed in the checklists. Then, for the other nodes (i.e. child nodes) a Conditional Probability Table (CPT) (also called link matrix) was specified. Once the probabilities for the input nodes were entered, the software calculated the probability for other nodes, which allowed us to determine the *effectiveness* of sections and the *overall effectiveness* of EISs.

There are three main types of algorithms that Netica can use to construct CPTs: counting, Expectation-Maximization (EM) and Gradient Descent (GD) (Norsys 2007). We used the "counting" algorithm because there were no missing data or uncertain findings for the child nodes or their parents. This algorithm uses frequency counts of child states given each possible parent (Pollino et al. 2007).

2.4.1. Sensitivity analysis

The sensitivity of the effectiveness of sections to particular variables was assessed by applying *sensitivity to findings* in the Netica software (Pollino et al. 2007). Sensitivity analysis is one way to evaluate a Bayesian network. Sensitivity analysis is used to determine how the probability of the endpoint variable responds to changing probabilities in inputs between 0–1 (Pollino et al. 2007a, Pollino et al., 2007b). Plots show the ranking of importance of input variables, from the most (bottom) to least (top) sensitive variable, to the endpoint variable (*overall effectiveness*).

The Netica software quantifies sensitivity to findings by two types of measures: *Entropy* and *Mutual information*. Entropy (H) relates to the evaluation of uncertainties or randomness of a variable (X) characterized by a probability distribution, *P(x)* (Pearl 1998; Korb and Nicholson 2004; Pollino et al. 2007):

$$H(X) = -\sum_{x \notin X} P(x) \log P(x)$$

Mutual information (I) is used to measure the effect of one variable (X) on another (Y) (Korb and Nicholson 2004; Pollino et al. 2007):

$$I(X,Y) = H(X) - H(X|Y)$$

where $I(X,Y)$, is the mutual information between variables.

3. RESULTS

3.1. Descriptive statistics for Iranian EISs from 1996–2006

3.1.1. Methodological features

Using existing databases and reviewing literature were the most common approaches for data collection in Iranian EISs. Maps were used as data source in 19% of the statements, aerial photographs as well as satellite images in one statement. Only for 3% of the statements new surveys had been carried out and none of the statements had used questionnaires. These results show a considerable potential for improving methods of data collection, which should be more specific for the particular project under consideration.

The assessment of potential impacts was most frequently done with Leopold Matrices and checklists (51% and 63% of all statements, respectively). Only one EIS used the overlay approach. Quantitative approaches for assessment were never used.

3.1.2. Biological variables considered

The ecosystem types potentially affected by projects, based on their consideration in the corresponding EISs in Iran, are listed in Fig. 2. Grasslands were most often considered as potentially affected, followed by rivers and mountains. Some projects even risked to affect unique and fragile ecosystems such as mangroves and coral reefs.

Because of the importance of designated areas (national parks, protected areas, wildlife refugees, natural reserves, etc.) for biodiversity conservation, we studied also the potential impacts of development projects on such areas (Fig. 3a) as well as potential impacts on wildlife species mentioned in the corresponding EISs (Fig. 3b). Protected areas were most often considered as potentially affected, but even national parks and highly sensitive Ramsar sites were considered to be threatened by several projects. The latter are already threatened in Iran by drought and other consequences of climate change. Not surprisingly, mainly large mammals and birds were considered as potentially threatened by development projects; threatened plant species were considered by only 10% of, and invertebrates were never considered in the investigated EISs. Out of 144 mammal species in Iran, 25 species (18%) are recorded in the IUCN Red List (IUCN 2006).

3.1.3. Changes in numbers of identified impacts

The number of identified impacts per EIS tended to increase from 1996–2006 ($F_{1,8}$= 4.02, P= 0.07). On average, twice as many physical than biological impacts were identified per EIS (18.8 vs. 6.9, Fig. 4a). The number of identified physical impacts per EIS increased significantly from 1996–2006 ($F_{1,8}$= 5.56, P=0.04, Fig. 4a), but identified biological impacts did not significantly increase ($F_{1,8}$=1.53, P=0.25, 4a). The average number of mitigation measures and monitoring actions per EIS also increased over the years (Fig. 4b).

3.1.4. Differences in identified impacts among project types

The effectiveness of impact identification in different project types is shown in Fig. 6. The results show that physical impacts have been more effectively identified than biological impacts in the EISs. Physical impacts were most often identified in EISs for the project types *Marine port, Mining, Agriculture, Irrigation and drainage systems, and Railways and roads*. EISs for the project types *Water transferring, Agriculture, Irrigation and drainage systems* as well as *Dam construction and Hydro-power plants* were most effective in identifying biological impacts. The EISs of *Cement plants* did not identify any biological impacts.

The effectiveness of the mitigation plan for different project types is shown in Fig. 7. The figure shows the highest effectiveness of EISs for *Slaughter houses*. This is because we had only one statement for this project type. EISs for *Agriculture*, *Irrigation and drainage systems* as well as *Water transferring* had more effective mitigation plans than EISs for others project types. While *Mining*, *Steel meting plants* and *Power plants* are of the most frequent projects in Iran and have major effects on the environment; their mitigation plans had low effectiveness.

The effectiveness of the monitoring plan for different project types is shown in Fig. 8. In general, physical variables were given preference over biological variables in the monitoring plans for all types of projects. In addition, monitoring of biological variables for more than half of the project types has not been recommended in the EISs. This was even the case for major projects of the type *Mining, Steel melting plants, Cement plants, and Refineries and oilfield developments,* which can have a major effect on the biological environment. EISs for *Water transferring* projects had the most effective monitoring plans. For this project type, as well as for the project types *Agriculture, Irrigation and drainage systems* and *Dam construction and hydro-power plants* monitoring of biological variables was recommended even more strongly than monitoring of physical variables.

3.2. Effectiveness of Iranian EISs as evaluated by Bayesian network analysis

3.2.1. Overall effectiveness

Here we present the results of the overall effectiveness of EISs based on calculating the effectiveness for the sections *Scoping*, *Mitigation plan*, and *Monitoring plan* (Fig. 5). We exclude some sections of EISs such as *Description of the environment* and *Description of* *the project* from this study. This was because we believe that these sections usually are being considered effectively in EISs in Iran. However, effectiveness of the studied sections needs to be evaluated and improved. The ‘overall effectiveness’ of the 96 EISs, based on the studied sections, as well as the effectiveness of each section and sub-sections of the EISs are shown in Fig. 5. As it is shown in the figure, the overall effectiveness of all the studied sections is equal to 15.2%. The effectiveness of the *Mitigation plan* was highest (17.3%), whereas *Scoping* was least effective section (14.3%).

3.2.2. Effectiveness of scoping sections

With regard to *Impacts origin*, about 5% of the EISs identified cumulative impacts and 32% identified indirect impacts. *Impacts identification* as well as *Impacts evaluation* was done less effectively for the operation phase than for the construction phase of projects. This was true for both physical and biological impacts. With regard to *Impacts evaluation*, overall, 19.7% of the expected physical impacts of the projects were evaluated. Impacts, which were related to *Habitat damage* and *Disturbance*, were identified more frequently than other physical impacts (47.3% and 46.7% respectively). Impacts at habitat scale were identified more frequently than impacts at landscape scale (33.6% vs. 5.9%). Impacts, which are related to *Habitat insularization* were identified and evaluated only in one EIS. The effectiveness of biological impacts identification was 16.9% and was lower than for physical impacts. *Wildlife mortality* impacts were considered more frequently in the EISs than *Biological alteration* and *Ecosystem functions* impacts (23.5 vs. 19.0 and 8.7).

3.2.3. Effectiveness of mitigation plan sections

The effectiveness of the *Mitigation plan* section was 17.3% for our studied EISs (Fig. 5). Measures related to *Compensation* were often suggested in the EISs. However, *Rescue, Relocation, and Translocation* measures were completely neglected.

3.2.4. Effectiveness of monitoring plan sections

The effectiveness of the *Monitoring plan* section was 14.2% for our studied EISs (Fig. 5). In the monitoring plans, biological variables were suggested to be monitored less often than physical variables. This corresponds to the fact that fewer biological than physical impacts were identified (see 3.2.2.). *Monitoring of noise* variables was most frequently suggested in the *Monitoring plan* section of the EISs.

3.3. Ranking influential variables

Using Netica software for sensitivity analysis for the studied EISs, the most influential link to the *Overall effectiveness* node was the *Mitigation plan* (Table 2; Fig. 9). Following, the next most influential variables were *Methodology*, *Monitoring plan* and *Scoping. Monitoring of physical variables*, *Monitoring of biological variables* as well as *Impacts origin* greatly influenced the *Overall effectiveness*. Sensitivity analysis showed that the mitigation measures input nodes were the most influential among all input nodes for the *Overall effectiveness*. *Indirect impacts* was the next most influential input node. The influence of the *Physical impacts* node on the *Overall effectiveness* was stronger than that of the *Biological impacts* node. However, *Biological impacts* parent nodes had greater influence on the *Overall effectiveness* than *Physical impacts* parent nodes.

4. DISSCUSSION

As the principles of the EIA are similar in different countries (Glosson 2000), the EIA practices have similar shortcomings and EIA is still far from perfect globally (Ahammed, 2006). For example, often assessments of all project alternatives are poorly described (Barker and wood, 1999; Steinemann 2001; Pinho et al., 2006). In addition, cumulative impacts are often not being considered adequately (Brismar 2004; Sadler et al., 2000) and the assessment of the impacts of the projects on biological variables, particularly biodiversity, is globally not satisfactory yet. The “biodiversity” term is seldom used in the studied EISs (Atkinson et al., 2000; Gontier et al., 2006) and not enough attention is paid to biological variables at different scales (Gontier et al., 2006) such as genetic, species, community and ecosystem diversity as well as ecological interactions (Atkinson et al., 2000; Mandelik et al., 2005). Hence impact assessments, particularly assessment of impacts on biodiversity, are mostly descriptive and without temporal and spatial scales (Mandelik et al., 2005; Gontier et al., 2006).

We evaluated the effectiveness of Iranian EISs prepared from 1996–2006. The results showed an overall effectiveness of 15.2%. This low effectiveness is not satisfactory for an EIA system with more than 14 years experience. It should be noted that if we could include the other two sections (i.e. *Description of the project* and *Description of the environment*), the overall effectiveness could increase. However, the effectiveness for the analyzed sections *Scoping, Mitigation plan* and *Monitoring plan,* which are the key elements of EIA, is most critical for EISs. Among the statements for different project types, we found that the EISs for the project types *Water transferring, Agriculture, Irrigation and drainage systems*, *Dam construction and hydro-power plants* and *Railways and roads* were the most effective ones.

The quality of data as well as the assessment method can play a vital role in the effectiveness of an EIA. In our study, we found that usually data were not being collected from effective sources. In addition, practitioners did not apply the best approaches in assessment. Although *Leopold matrix* and *Checklists* are most frequently used in Iran and considered suitable approaches for impact identification (DoE and UNDP 2001), only 18.3% of all the expected impacts were identified.

Surprisingly, indirect impacts of the projects were considered in more than 32% of the statements. However, cumulative impacts were rarely considered although the legal basis of EIA in Iran calls for it (see chapter 4). We found that grasslands, followed by rivers and mountains were most often potentially affected by projects, but even unique ecosystems were at risk in some cases. Hence, we expected a greater consideration of biological than physical impacts in the EISs. However, this was only the case in of one of the project types (see Fig. 6). We found also that not enough attention was paid to likely impacts at the landscape scale, although habitat fragmentation and isolation are known to be strong drivers of biodiversity loss (Thuiller et al. 2005).

One of the major and immediate problems of the investigated Iranian EISs was that *Mitigation plans* and *Monitoring plans* were not presented as well-structured sections. For example, sometimes, a schedule for mitigation or monitoring was though suggested but the responsible organizations were not identified and financing plans not presented. Often the suggested mitigation measures did not seem to be the most appropriate ones considering the planned project activities and expected environmental conditions and usually were prepared in a quite speculative way. Project types with a high risk of destruction (e.g. *Cement plants, Mining*) as well as those with a high risk of pollution (e.g. *Power plants, Refineries, Steel melting plants*), which consequently have most likely significant impacts during the construction, operation and decommissioning phases, had EISs in which effects on biological variables were not considered in monitoring plans.

Although our findings showed that EISs in Iran were often not prepared in the most effective way, we found that there was a tendency for improvement over the 11 years. The number of identified physical impacts, mitigation measures and monitoring actions increased significantly from 1996–2006. The increasing number of practitioners obtaining more experience apparently had a positive influence on the effectiveness of the EISs. However, improvements regarding biological impact identification could not be observed. Nowadays, Iranian ecosystems, in particular wetlands, are experiencing a high pressure by climate change (IPCC 2007). In addition to that, construction of large dams on the main rivers, high level of exploitation of wetlands, diversion of water for domestic consumption, irrigation purposes and industrial uses pose particularly large threats to wetlands (Scott 1995). Protected areas containing highly vulnerable species are also at particularly high risk. Therefore, a better consideration of biological variables in Iranian EISs would be vital. To improve the effectiveness of the statements, first more attention should be given to the review stage in the EIA bureau of the DoE in Iran. Thereby, the neglected aspects and poor structure in scoping and mitigation or monitoring plan could be recognized and improvements be requested. Second, more attention should be paid to the effectiveness of statements, using for example the framework and data basis presented in this paper.

Our findings revealed that not only the overall effectiveness of the investigated Iranian EISs is low, but also the consideration of biological impacts is insufficient. We conclude that impacts of the projects on biodiversity components and ecosystem functions should be taken into account at all stages of EIA and in all sections of EISs.

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Table 1 Number of Environmental Impact Statements (EISs) archived in the EIA Bureau of Iran from 1995–2004 grouped according to provinces (left, a) and classification into project types of 96 EISs from 1995–2006 analyzed in this study (right, b). As EIA provisions in Iran were adopted in 1994, first EIS were archived in the EIA Bureau in 1995. At the time of data collecting, 2006, only the EISs prepared in 2004 and before were archived. However, the EIS of 1995 were not accessible. EISs prepared in 2005–2006 were collected from environmental consulting firms; they are not included in a).

a) Province	**# of EISs**
Ardabil	1
Bushehr	10
Charmahal&Bakhtiari	11
East Azerbaijan	8
Fars	7
Gilan	16
Golestan	10
Hamadan	7
Hormozgan	33
Ilam	4
Isfahan	15
Kerman	12
Khorasan	17
Khuzestan	47
Kohkeluye & Boyerahmad	5
Kurdestan	2
Lorestan	9
Markazi	6
Mazandaran	27
Qom	5
Semnan	4
Sistan& Baluchestan	9
Teheran	30
West Azarbaijan	16
Yazd	12
Zanjan / Ghazvin	14
Total	**337**

b) Project type	**# of EISs**
Agriculture / irrigation and drainage systems	3
Aquaculture farms	6
Cement plants	2
Compost / recycling / landfills	5
Dam constructions / hydro-power plants	8
Industrial complexes	10
Railways / roads	7
Steel melting plants	10
Refineries / oilfield developments	7
Marine ports	2
Mining	5
Oil & gas pipeline / reservoirs	11
Petrochemical plants	3
Power plants	7
Slaughter houses	1
Tourism complexes	6
Water transferring	3
Total	**96**

Table 2 Sensitivity analysis for the influence of different variables in the EISs on the overall effectiveness, showing mutual information (Mutual Info) and entropy (Variance of beliefs). The variables are ordered in the sequence of declining influence on the *Overall Effectiveness* of the EISs (Mutual Info). See text for further details about method.

Node	Mutual Info	Variance of Beliefs
Mitigation plan	0.07435	0.0158066
Monitoring plan	0.06151	0.0134573
Scoping	0.04985	0.0111699
Physical monitoring	0.01717	0.0034218
Biologic monitoring	0.01654	0.0033064
Impacts origin	0.00986	0.0018524
Monitoring of ecosystem productivity	0.00620	0.0011337
Impacts identification	0.00538	0.0010448
Reducuction / moderaation / minimization	0.00522	0.0009219
Compensation	0.00481	0.0008562
Avoidance	0.00416	0.0007489
Indirect impacts	0.00381	0.0006646
Impacts evaluation	0.00364	0.0007135
Monitoring of species density	0.00240	0.0004557
Repair / reinst./restor.	0.00194	0.0003591
Impacts nature	0.00164	0.0002999
Physical impacts	0.00144	0.0002626
Biological impacts	0.00142	0.0002598
Monitoring of Waste / disposal / treatment	0.00116	0.0002023
Air & Noise	0.00102	0.0001793
Cumulative impacts	0.00082	0.0001501
Water monitoring	0.00080	0.0001416
Habitat-scale impacts	0.00050	0.0000871
Soil & sediment	0.00048	0.0000850
Monitoring of landscape aspects	0.00036	0.0000656
Monitoring of noise	0.00032	0.0000555
Landscape-scale impacts	0.00024	0.0000422
Monitoring of surface water	0.00022	0.0000376
Monitoring of undgrnd water	0.00019	0.0000331
Biological alteration	0.00018	0.0000319
Monitoring of air variables	0.00018	0.0000309
Wildlife mortality	0.00016	0.0000277
Ecosystem functions	0.00015	0.0000266
Spatial & temporal dimens.	0.00015	0.0000266
Monitoring of sediment variables	0.00013	0.0000225
Monitoring of soil variables	0.00012	0.0000200
Lanscape change	0.00010	0.0000180
Habitat damage	0.00003	0.0000051

Node (*continued*)	**Mutual Info**	**Variance of Beliefs**
Disturbance	0.00003	0.0000048
Duration	0.00002	0.0000035
Timing	0.00002	0.0000029
Pollution	0.00002	0.0000027
Extent	0.00001	0.0000024
Physical alteration	0.00001	0.0000023
Habitat insularization	0.00001	0.0000023
Habitat loss	0.00001	0.0000019
Evaluating dimens.	0.00001	0.0000019
Magnitude	0.00001	0.0000018
Description dimens.	0.00001	0.0000013
Revesibility	0.00000	0.0000003
Avoidability	0.00000	0.0000002
Rescue / relocation / translocation	0.00000	0.0000000
Certainty	0.00000	0.0000000
Importance	0.00000	0.0000000
Frequency	0.00000	0.0000000

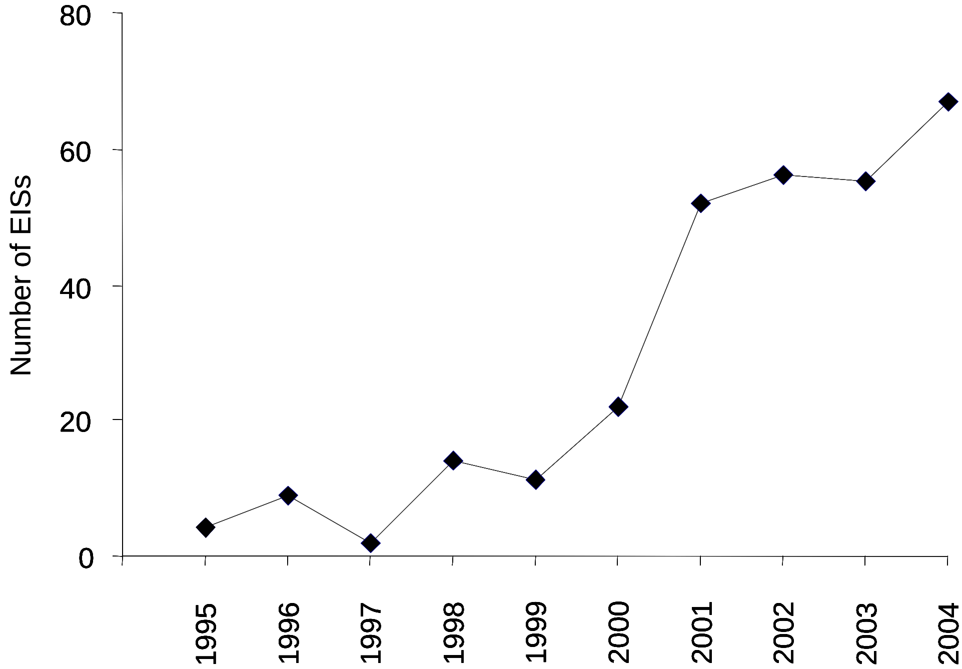

Fig. 1 Number of Environmental Impact Statements archived in the EIA Bureau in Iran from 1995–2004 (see Table 1a).

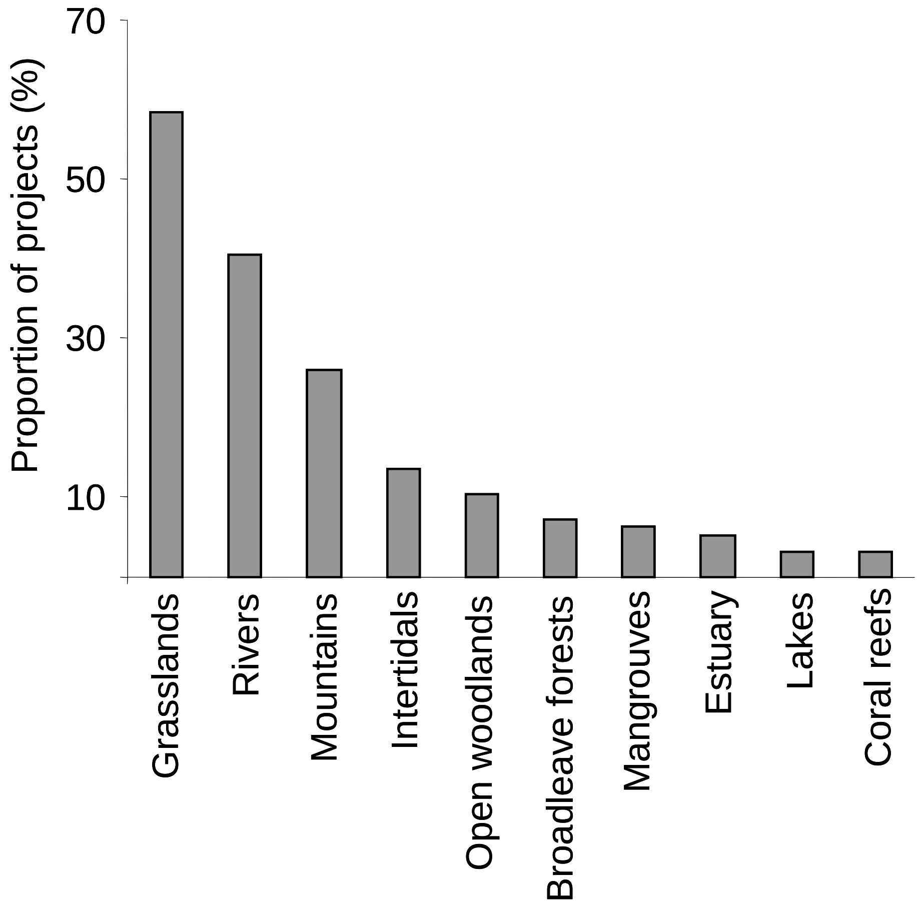

Fig. 2 Proportion of projects potentially affecting the 10 ecosystem types listed on the x-axis (based on whether the particular ecosystem type was mentioned in the EIS of the corresponding project).

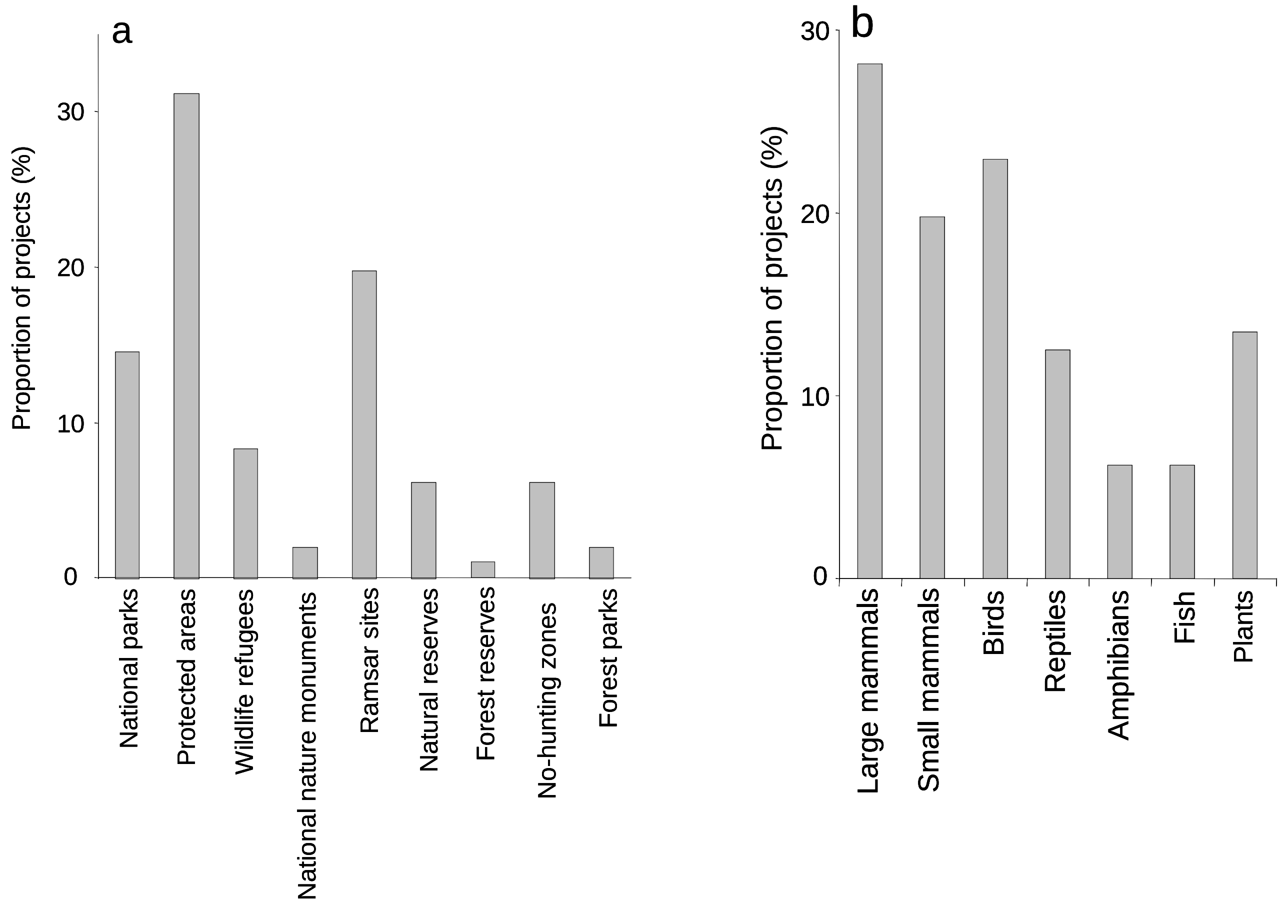

Fig. 3 a) Proportion of projects potentially affecting the designated areas listed on the x-axis (based on whether the particular designated area was mentioned in the EIS of the corresponding project); b) proportion of projects potentially affecting Red List animal and plants species of the groups listed on the x-axis (based on whether animals of the particular group were mentioned in the EIS of the corresponding project).

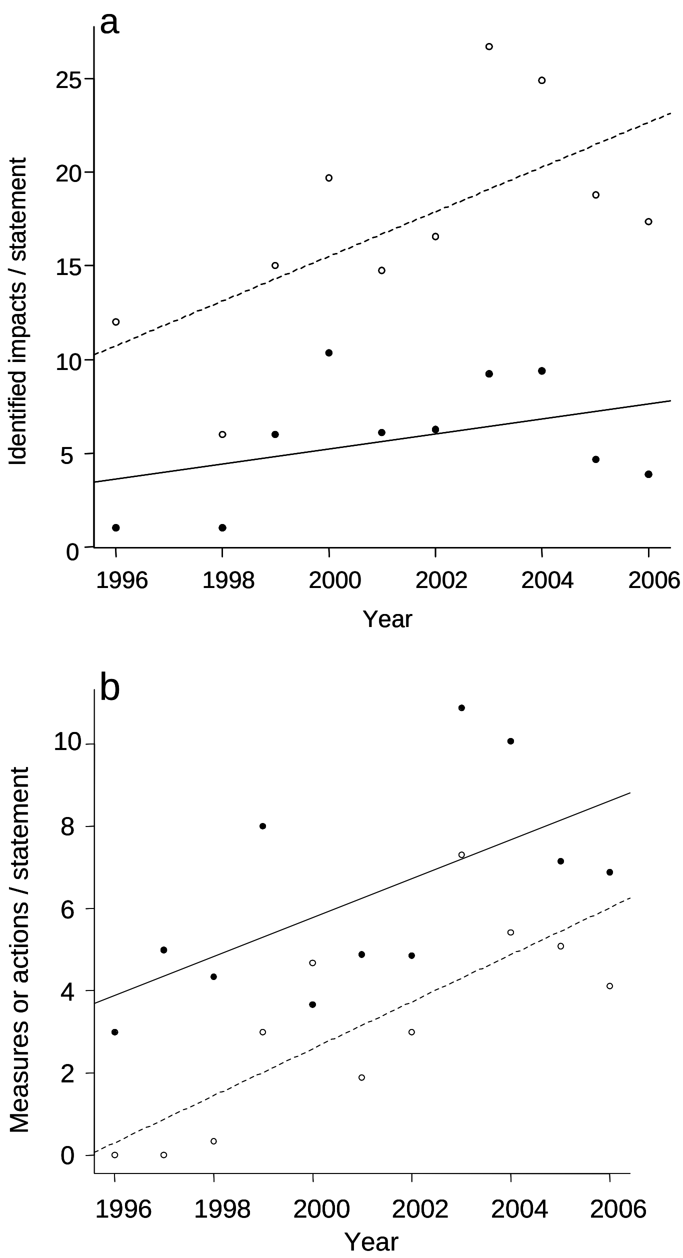

Fig. 4 Changes from 1996–2006 in a) the number of identified physical (white points, dashed line) and biological impacts (black points, solid line) and b) the number of mitigation measures (black points, solid line) and monitoring actions (white points, dashed line) per EIS in Iran.

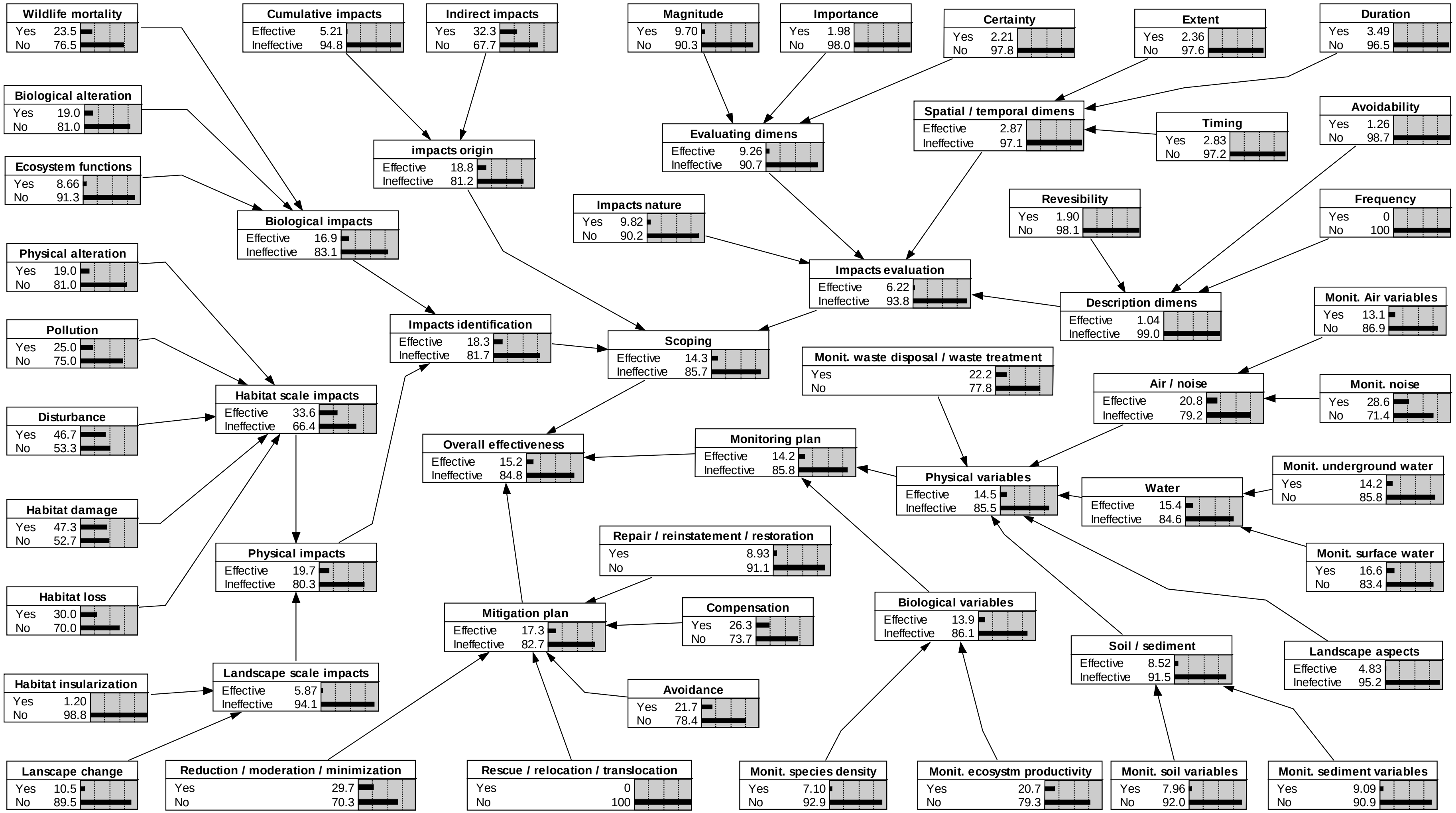

Fig. 5 Effectiveness of the sections and sub-sections of the EISs in Iran as calculated by Bayesian network analysis (see text for detailed explanation).

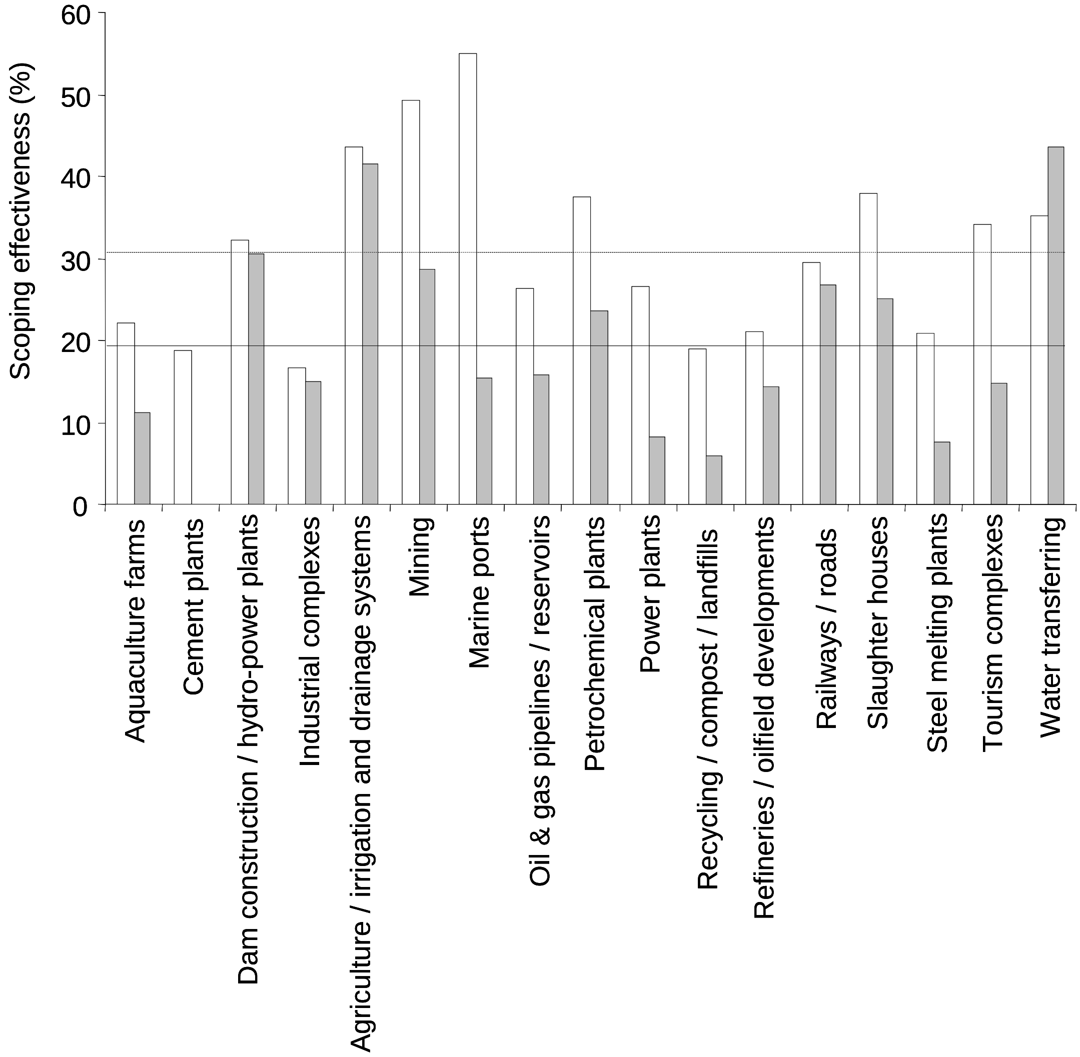

Fig. 6 The effectiveness of the scoping section in Environmental Impact Statements for different project types. White bars, dashed line: physical impacts; grey bars, solid line: biological impacts. The horizontal lines show the mean effectiveness.

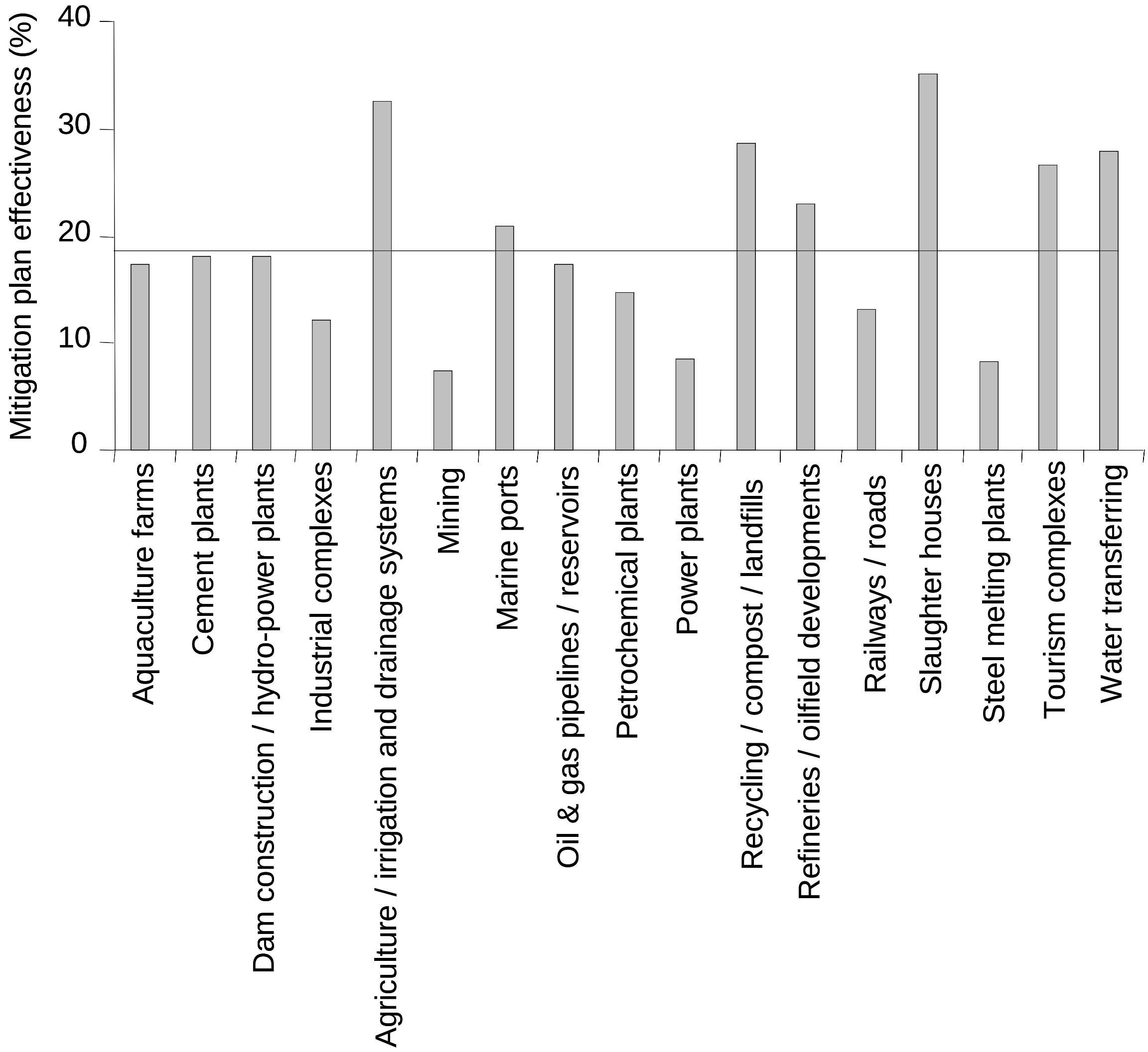

Fig. 7 The effectiveness of the mitigation plan section in Environmental Impact Statements for different project types. The horizontal line shows the mean effectiveness.

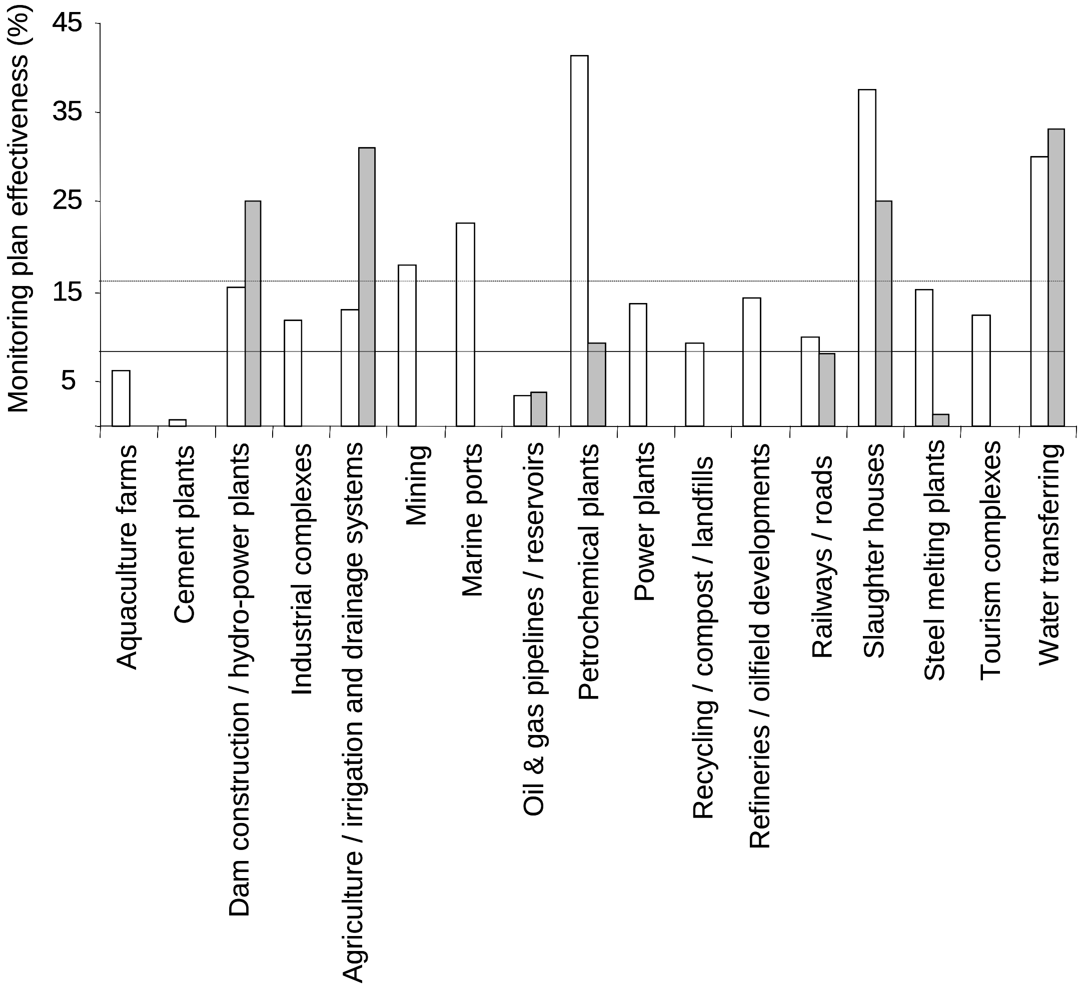

Fig. 8 The effectiveness of the monitoring section in Environmental Impact Statements for different project types. White bars, dashed line: physical variables; grey bars, solid line: biological variables. The horizontal line shows the mean effectiveness.

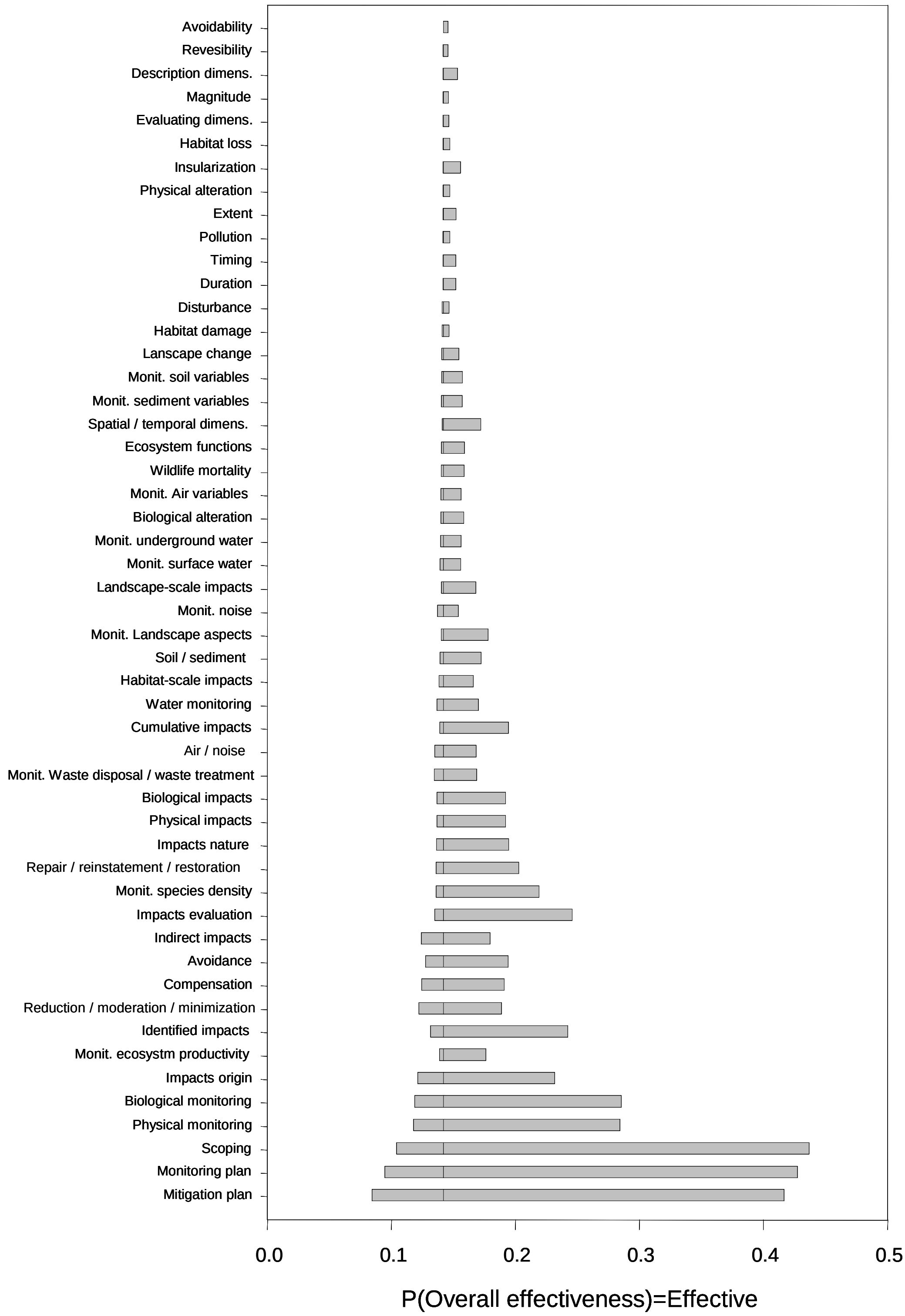

Fig. 9 Sensitivity of the mean probability for 'Overall effectiveness' when is set to effective. Variables are listed from the least influential (top) to the most influential (bottom). Bars represent the range in variation observed in the 'Overall effectiveness' node when the values of the variables on the y-axis were varied from 0 to 1.

6

General discussion

In my PhD thesis, I conducted both, an observational study on the effects of climate change on biodiversity in fen meadows in Switzerland; and a practical review, evaluation and assessment of the legal basis as well as the effectiveness of environmental impact assessment (EIA) and environmental impact statements (EISs) in Iran. In the observational study, I show how climate change can affect the biodiversity of endangered, species-rich fen meadows in the Swiss Alps and investigate the responses of different plant functional groups in fen meadows to climate and other environmental changes. In the practical review, I evaluate the Iranian EIA system. I review the history of implementation and explore the legal basis and the Iranian guidelines of EIA. The quality of EIA was investigated by evaluating the effectiveness of 96 EISs, which are the essential part of every EIA system.

To date, although the necessity of consideration of climate change in EIAs is acknowledged (CEAA 2003; IPCC 2007), there are not many data based on field studies that show the biological consequences of climate change (Thuiller 2007). As the results of our observational study indicate, effects of climate and other environmental changes on biodiversity can become visible after 10 years already. These results suggest that EIA scientists and practitioners should be aware that the environment affected by developmental projects is already under pressure by the effects of global change. However, biodiversity by itself is hardly considered in EISs and global change as an additional driver affecting the natural environment is similarly rarely included in the statements. We recommend that these aspects should always be included in future EIA and EISs. However, further research will be needed to allow more rigorous analysis of effects and impacts of climate change and developmental project, respectively, on biodiversity.

In **chapter 2** I show that despite legal protection and no obvious change in the traditional management system in the montane fen meadows investigated, a significant decline in species density of fen specialists and a concomitant increase in species density of other groups of vascular plants occurred from 1995–2005/06. Within the last 30–50 years, daily mean, minimum and maximum temperatures increased significantly in the study region. The mean annual precipitation, however, remained relatively constant over this time period (Bergamini *et al.* 2009). In our pre-Alpine fen meadows, the colonization rate of climate change indicators (early-flowering and warm-temperature species) exceeded their extinction rate significantly. Late-flowering species that might benefit from the observed longer vegetation period, however, had lower colonization (and extinction) rates. These late flowering species might have been prevented from spreading under the potentially more favorable climatic conditions by the mowing treatment in late summer. The only group of species, which had a higher extinction than colonization rate were fen specialists.

During the 10-year observation period, our fen sites increased in productivity and therefore shadiness presumably increased as well. The higher productivity in our fens might in part explain the lower total soil nitrogen measured in the 2005/06 than in the 1995 survey. Fen specialists seem to be rather inflexible under environmental change (Erschbamer 2007), whereas species with a low habitat-specificity presumably can react more plastically to such change. Thus, the latter indeed had higher colonization than extinction rates in our fen meadows. Warm temperature as well as rich-soil species and shade indicators had the highest colonization rates during the 10-year observation period and obviously were not negatively affected by the observed increase in temperature and other drivers such as habitat fragmentation and isolation (Lienert *et al.*, 2002; Fakheran *et al.*; unpublished data) as well as nutrient spill-over from intensively used adjacent areas and increased atmospheric nitrogen deposition (Klötzli, 1986; Pauli *et al.*, 2002). Because changes in soil nutrients were neither significantly related to the colonization nor to the extinction rate of any putative climate-change indicator, we conclude that the observed increase in species densities of the above-mentioned groups of was most likely caused by climate warming and other possibly more subtle environmental changes.

Also at a small plot scale of 2 x 2 m (**chapter 3**), species density of habitat specialists and Red-List species of calcareous fens in the Swiss pre-Alps significantly decreased over the decade from 1995–2006. The decline in habitat specialists and Red-List species at the study sites was correlated with a decline in habitat quality. We observed an increased aboveground vascular plant biomass, an increase of the species density of nutrient indicators and a decrease of in mean peat-indicator values. These findings suggest an eutrophication and decreasing soil moisture at the fen sites. They became more productive, richer in nutrients, shadier at the ground and drier, thus making it difficult for small, non-competitive, fen-adapted species to survive. In our study, the increase of the mean nutrient-indicator values was caused by two processes: the decrease of habitat specialists and the increase of nutrient-indicator species. Also the decrease of bryophyte species density in our study was likely caused by eutrophication that led to an increase of vascular plant biomass, but not of bryophyte biomass (Bergamini et al. 2001). Due to the experimentally shown N-limitation of aboveground biomass production in our fens (Pauli et al., 2002), high atmospheric nitrogen deposition has the potential to cause the observed changes (see also Stevens et al., 2004).

In **chapter 4** I describe the considerable progress that has been made in the past 14 years of the implementation of an EIA system in Iran. The legal basis for implementation of EIA exists in Iran and must be followed. However, there are still several problems and shortcomings in the procedure at the different stages of EIA. For example, for key stages such as report review, public participation and consultation or system monitoring and cost and benefits analysis there are no published guidelines available that would help proponents of projects and evaluation authorities. For this, it would be useful if the existing legal framework could be combined into a new, independent law. The law should have clear definitions of environmental impacts of development projects and of the aim and nature of EIA. The EIA-process should be structured clearly and the role of stakeholders, proponents, public and all other organizations involved should be explained. Furthermore, the penalties applicable in case of violating the law should be included in the law. The EIA Bureau or DoE should be required to publish decisions concerning all EIAs carried out for the different development projects. In any EIA system, consultation and public participation could improve the quality of environmental decisions (Wood 2003) and could have a major influence on the EIA effectiveness (Morrison-Saunders 2001). The public in Iran has become more environmentally knowledgeable and concerned over the past 12 years, but sill a higher rate of public involvement is needed.

In a quantitative study we analyzed 96 EISs to assess the quality of the Iranian EIA system (**chapter 5**). Using Bayesian network analysis, we found that practitioners rarely applied optimal approaches in EISs. We calcualted an overall effectiveness of only 15.2 % for all 96 EISs studied. The Mitigation-plan section had the highest and the Scoping section had the lowest effectiveness. We found that grasslands are the most, and rivers and mountains are the next most likely affected ecosystems by developmental projects in Iran. In general, biological impacts were not sufficiently identified and more than 88% of the projects focused on physical impacts more than on biological impacts. Mitigation and Monitoring plans were rarely prepared as a well-structured plan in the EISs. Furthermore, biological parameters often were also neglected or less considered in Monitoring plans and some projects, which have a high rate of destruction, have not suggested any biological variables in monitoring plans. Nevertheless, we found that the quality of EISs in Iran has improved from 1996–2006. The number of identified physical impacts, mitigation measures and monitoring actions significantly increased. As the EISs review process in the EIA bureau is playing a vital role regarding the effectiveness of the EISs, strengthening this process by preparing an appropriate checklist as well as enhancing staff capacity would further improve the quality of the EIA system in Iran.

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7

Summary

This thesis consists of two major parts: it discusses effects of multifactorial environmental changes (e.g. climate change and nitrogen deposition) and management type on plant diversity of species-rich fen meadows of high conservation concern in Switzerland. Secondly, the role of biodiversity in environmental impact statements in Iran is investigated and the history, operational workflows and the effectiveness of the Iranian system of Environmental Impact Assessment (EIA) is reviewed and discussed.

In **chapter 2,** I present a comparative field study on the changes in vegetation composition in protected, species-rich fen meadows in the foothills of the Swiss Alps (800–1400 m a.s.l.). In this study, which we conducted over 10 years from 1995/97–2005/06, we investigated: 1) whether species density changed with altitude over the 10–year period; 2) if so, which functional groups (i.e. fens specialist species, warm temperature species, shade indicators, early or late flowering plants) responded positively or negatively over time; and 3) whether changes in species density of any group were correlated with changes in abiotic soil variables or with plant community-level changes e.g. in biomass production. Within 10 years, the species density per site of all vascular plants increased significantly (the analysis in this chapter was based on 36 cumulative plots of 10 m^2 plots (i.e. 5 plots of 2m^2 in each site). While species numbers of putative profiteers of climate change and other environmental change increased during that time period, species numbers of fen specialists significantly declined. The main shift in vegetation composition occurred at the low-altitude sites, which overall had a higher colonization rate than higher-altitude sites. Especially warm-temperature species colonized more often than they went extinct. Early flowering species had a high colonization rate in grazed, but not in mown fens and especially colonized low-altitude grazed fens. Furthermore, species with low habitat specificity especially colonized fens at low altitudes. Finally, a large number of shade indicators colonized sites at all altitudinal levels, presumably due to increased community biomass and therefore increased shading. During the observation period, our fen sites increased in productivity, although soil concentrations of NO_3^- and PO_4^{3-} did not change significantly. We conclude that the observed changes in plant species distributions at our field sites, especially the increases in warm-temperature and generalist species, was probably mainly due to an increase in temperature and a prolonged vegetation period.

Chapter 3 focuses on small-scale diversity patterns of fen specialists and habitat quality in two management regimes, mown or grazed. As we found in chapter 2, despite traditional management regimes, species density of fen specialists and of all bryophytes decreased during the last decade (the analysis in this chapter was based on 180 plots of 2 m^2 (i.e. 5 plots in each of 36 sites). Interestingly, management had no effect on the number of Red-List species and habitat specialists of vascular plants. However, bryophyte species density was more strongly reduced in grazed fens. For bryophytes, the species loss was particularly severe for mosses in grazed sites. Among vascular plants, Red-List species decreased by 23% per plot. Furthermore, between the two surveys aboveground plant biomass, mean plant indicator values for nutrients and species density of nutrient indicators increased whereas mean plant indicator values for soil moisture, light and peat and species density for peat indicators decreased. We attribute these changes and the loss of specialist species over the past decade mainly to land-use change in the surrounding area, to nutrient inputs and to ongoing climatic changes. Thus, despite traditional management and subsidized conservation efforts, calcareous fens in the pre-Alps suffer from ongoing habitat deterioration and endangered plant species remain threatened.

Chapter 4 discusses the legal basis and effectiveness of the EIA system in Iran. On the basis of original sources in Farsi, the history of the environmental legislations and the EIA system in Iran are reviewed and the current state of EIA in Iran and shortcomings that the EIA process is facing are evaluated. We applied the evaluation criteria developed by Wood (2003) to assess the effectiveness of the legal basis (laws and guidelines) of the Iranian EIA system. We considered the criteria to identify gaps in all 14 individual stages of an EIA system (legal basis, coverage, alternatives, screening, scoping, report contents, report review, decision making, impact monitoring, mitigation measures, consultation and public participation, system monitoring, cost and benefits, as well as strategic environmental assessment). We show that although considerable progress has been made in the past 14 years concerning the implementation of an EIA system in Iran, there are still some shortcomings in the procedure at the different stages. There are parts of the Iranian EIA legal basis that could be used to develop guidelines for key issues such as 1) EIA report review, 2) public participation and consultation or 3) system monitoring and 4) cost and benefits analysis. The most important concern about EIA in Iran is that there is no specific

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and independent law regulating environmental impact assessments. Currently, EIAs are based on a Decree of "Law on Economical, Cultural and Societal Development" (ECSD). The law on ECSD regulates the structure and direction of the development for every 5-year period. It must thus be ratified by the parliament each time before a new period starts. For an effective and efficient EIA system, it would be useful if the existing legal framework could be combined into a new, independent and permanent law.

The EIA process should be clearly structured and the role of stakeholders, proponents, the public and all other organizations involved should be defined. Furthermore, the penalties applicable in case of violating the law should be included in the law. The public in Iran has become more environmentally knowledgeable and concerned over the past 12 years. In addition, environmental NGOs are becoming more active. Therefore, appropriate opportunities should be provided to inform and involve the interested and affected public, and their inputs and concerns should be addressed explicitly in the documentation and decision making of environmental impact assessments.

In **Chapter 5,** I estimated the effectiveness of 96 Environmental Impact Statements (EISs) as an indicator of the effectiveness of environmental impact assessment in Iran. Environmental Impact Assessment (EIA) was formally developed as a decision tool about 40 years ago. A number of studies assessed the legal basis of the EIA after several years of experience. However, the quality of EISs of projects has rarely been assessed. This quality plays a vital role in the decision-making process of development projects and can be used as an indicator of the effectiveness of an EIA system. In this study, we evaluated the effectiveness of Iranian EISs prepared from 1996–2006 using different checklists. The projects for which the statements were prepared could be classified into 17 types. We assessed the methodology used in the 96 EIS and the three most important sections of the EIS, i.e. scoping, mitigation plan, and monitoring plan.

We found that the methodological approaches in Iranian IESs were often not optimal and original data were rarely collected. According to our analysis, development projects most likely were going to affect grassland ecosystems, followed by rivers and mountains, but even rare and endangered ecosystems such as mangroves and coral reefs were sometimes at risk. However, biological impacts were not sufficiently assessed in most Iranian EISs and only the EISs of one project type considered biological impacts more strongly than physical impacts. Biological variables were often neglected in monitoring plans, even in EISs of projects with high risks of destruction of ecosystems.

Although the investigated EISs had low effectiveness (i.e. overall effectiveness of 15.2%), we found that there is tendency for improvement. The number of identified physical impacts and suggested mitigation measures and monitoring actions increased significantly from 1996–2006. Unfortunately no such improvement can yet be seen for biological impact identification. We conclude that impacts of development projects on biological variables should be taken into account at all stages of EIA and in all sections of EISs in Iran.

8

Zusammenfassung

Diese Dissertation besteht aus zwei Hauptteilen: Sie befasst sich erstens mit dem Einfluss von Umweltveränderungen, z.B. der Klimaänderung und dem atmosphärischen Stickstoffeintrag, sowie der Nutzungsform auf die biologische Vielfalt der Pflanzen in artenreichen Flachmoorwiesen mit einem hohen Schutzniveau im Nordosten der Schweiz. Zweitens werden betrieblicher Ablauf und Wirksamkeit einer grossen Zahl iranischen Umweltverträglichkeitsprüfungen (UVP) analysiert sowie die Berücksichtigung ökologischer Risiken in Umweltverträglichkeitsberichten beurteilt.

In **Kapitel 2** wird eine vergleichende Feldstudie vorgestellt, in der wir Veränderungen der Vegetationszusammensetzung in geschützten, artenreichen Flachmoorwiesen in den Schweizer Voralpen (800-1400 m ü. M.) zwischen 1995/97 und 2005/06 untersuchten. Dabei analysierten wir vor allem, ob 1) sich die Artendichte (= mittlere Anzahl Arten in fünf 1x2 m Probeflächen) innerhalb der 10 Jahre veränderte und falls ja, 2) welche funktionellen Pflanzengruppen (d.h. typische Moorpflanzen, wärmeliebende Pflanzen, Schattenpflanzen, früh- oder spätblühende Pflanzen) zu- oder abnahmen und 3) ob die Veränderung der Artendichte korreliert war mit Veränderungen abiotischer Bodenfaktoren oder Veränderungen der gesamten Pflanzengemeinschaft, z.B. der Biomassenproduktion. Die Analysen basieren auf 36 Flachmooren, in denen je 5 Flächen von 2 m^2 untersucht wurden.
Insgesamt nahm innerhalb der letzten 10 Jahre die Dichte der Gefässpflanzen an allen Untersuchungsstandorten signifikant zu. Während jedoch die Artenzahlen von Pflanzen, die vermutlich von Klima- und anderen Umweltveränderungen profitieren, zunahmen, nahmen typische Flachmoorarten zahlenmässig ab. Am stärksten veränderte sich die Zusammensetzung der Vegetation in den Untersuchungsgebieten auf niedrigeren Höhenstufen, die insgesamt eine höhere Besiedlungsrate aufwiesen als höher gelegene Standorte. Besonders wärmeliebende Pflanzen besiedelten häufiger neue Gebiete, als dass sie in bestehenden Verbreitungsgebieten ausstarben. Frühblühende Pflanzen wiesen eine hohe Besiedlungsrate auf in Flachmoorwiesen, die beweidet wurden, jedoch nicht in solchen, die gemäht wurden, dies besonders auf niederen Höhenstufen. Zudem besiedelten auch Arten mit geringer Habitatspezifität vor allem die Untersuchungsgebiete auf niederer Höhenstufe. Viele Schattenzeiger besiedelten Gebiete auf allen Höhenstufen, vermutlich infolge der Zunahme der Beschattung durch die erhöhte Biomasse der gesamten

Pflanzengemeinschaft. Während der Untersuchungsperiode nahm die Produktivität auf allen Untersuchungsflächen zu, obwohl die Konzentrationen von NO_3^- and PO_4^{3-} im Boden sich nicht signifikant veränderten. Wir schliessen aus unseren Ergebnissen, dass die beobachteten Veränderungen der Artenverteilung in unseren Untersuchungsgebieten, besonders die Zunahme der wärmeliebenden und generalistischen Arten, vermutlich vor allem auf die Temperaturerhöhung und die verlängerte Vegetationsperiode zurückgeführt werden können.

Die in **Kapitel 3** dargestellten Untersuchungen befassen sich vor allem mit dem Einfluss der beiden Bewirtschaftungsformen "gemäht" und "beweidet" auf die Diversität von Pflanzen, die auf Flachmoorwiesen spezialisiert sind. Da wir eine Abnahme der Artendichte auf Flachmoore spezialisierter Gefässpflanzen und aller Bryophyten gefunden hatten, identifizierten wir nun mögliche Ursachen für diese Abnahme. Bei den Gefässpflanzen nahm die Zahl der Rote-Liste-Arten pro Fläche signifikant ab. Interessanterweise hatte jedoch die Bewirtschaftungsform keinen Einfluss auf Rote-Liste-Arten und Habitat-Spezialisten. Bei den Bryophyten war die Artendichte auf beweideten Mooren stärker reduziert als auf gemähten. Dabei war der Artenverlust besonders gross bei Moosen auf beweideten Flächen. Zudem nahmen in der Beobachtungsperiode von 10 Jahren die oberirdische pflanzliche Biomasse, die mittleren Nährstoffzeigerwerte und die Artendichte der Nährstoffzeigerpflanzen zu, während die mittleren Zeigerwerte für Bodenfeuchtigkeit, Licht und Torf sowie die Artendichte für Torfzeiger abnahmen. Wir führen diese Veränderungen und den Verlust von spezialisierten Pflanzen während der letzten 10 Jahre vor allem auf veränderte Landnutzung im umliegenden Gebiet, erhöhten Nährstoffeintrag und Klimaveränderungen zurück. Daher leiden geschützte Flachmoorwiesen trotz traditioneller Bewirtschaftungsweise unter der anhaltenden Verschlechterung des Habitats und gefährdete Pflanzenarten bleiben bedroht.

Kapitel 4 befasst sich mit der gesetzlichen Grundlage und der Wirksamkeit des Systems zur Unweltverträglichkeitsprüfung (UVP) im Iran. Auf der Grundlage von Originalquellen in Farsi wurde die Geschichte der Umweltgesetzgebung und der UVP im Iran dargestellt und der momentane Stand der UVP sowie Schwächen im UVP-System bewertet. Wir verwendeten Kriterien von Wood (2003), um die Wirksamkeit der gesetzlichen Grundlagen

(Gesetze und Richtlinien) des iranischen UVP-Systems abzuschätzen. Mit Hilfe der Kriterien identifizierten wir Lücken in allen 14 Phasen des UVP-Systems. Wir zeigen, dass bei der Implementierung des UVP-Systems in den letzten 14 Jahren beträchtliche Fortschritte gemacht wurden, während es in verschiedenen anderen Phasen noch einige Mängel zu verzeichnen gibt. Die UVP-Gesetzgebung im Iran könnte benutzt werden, um Richtlinien für Schlüsselprobleme zu entwickeln, so z.B. für 1) die Beurteilung des Umweltberichts, 2) die Partizipation der Öffentlichkeit, 3) die Erfolgskontrolle des UVP-Systems und 4) Kosten-Nutzen-Analysen. Die grösste Schwäche des UVP-Systems im Iran ist, dass es kein unabhängiges Gesetz für die UVP gibt, sondern dass die UVP nur in einem Absatz im "Gesetz über ökonomische, kulturelle und soziale Entwicklung" geregelt ist. Dieses Gesetz legt Struktur und Richtung für die gesamte ökonomische, soziale und kulturelle Entwicklung jeweils für 5 Jahre fest. Es muss ratifiziert werden durch das Parlament, bevor die nächste Zeitperiode beginnt. Dafür wäre es nützlich, wenn die bestehenden gesetzlichen Rahmenbedingungen in einem neuen, eigenständigen Gesetz zusammengefasst würden. Der UVP-Prozess sollte klar strukturiert und die Rolle von Stakeholdern, Gesuchstellern, Öffentlichkeit und involvierten Organisationen definiert werden. Ausserdem sollten Strafmassnahmen, die beim Überschreiten des Gesetzes zur Anwendung kommen, im Gesetz enthalten sein. In den letzten 12 Jahren ist die Öffentlichkeit im Iran umweltbewusster geworden und NGOs werden immer aktiver. Deshalb sollten angemessene Möglichkeiten für die Information und die Partizipation der interessierten und betroffenen Öffentlichkeit geschaffen werden und deren Beiträge sollten explizit in die Richtlinien und die Entscheidungsfindung einfliessen.

In **Kapitel 5** beurteilten wir die Wirksamkeit bestehender Umweltverträglichkeitsberichte (UVBs) als Indikator für die Wirksamkeit der UVP im Iran. Die UVP wurde vor 40 Jahren als Instrument für die Entscheidfindung entwickelt. Verschiedene Studien beurteilten die gesetzliche Grundlage der UVP nach mehreren Jahren Erfahrung. Jedoch wurde die Qualität der UVBs selten untersucht. Diese spielt jedoch bei Projekten für neue Anlagen eine entscheidende Rolle im Entscheidungsprozess und kann als Indikator für die Wirksamkeit der UVP herangezogen werden. In dieser Studie beurteilten wir die Wirksamkeit von 96 UVBs im Iran zwischen 1996 und 2006 anhand von verschiedenen Checklisten. Die Anlagen, für die ein UVB erstellt wurde, können in 17 verschiedene Kategorien eingeteilt werden. Untersucht wurden die verwendete Methodik sowie die wichtigsten Teile des UVBs, d.h. der Rahmen, der Massnahmenplan für die Verminderung der Umweltbelastung und der Massnahmenplan für das Monitoring.

Wir fanden, dass die methodischen Ansätze bei iranischen UVBs oft nicht optimal waren, da z.B. selten Orignialdaten erhoben wurden. Gemäss unseren Analysen, haben neue UVP-pflichtige Anlagen sehr wahrscheinlich einen negativen Einfluss besonders auf Grasland-Ökosysteme, aber auch auf Fliessgewässer- und Gebirgsökosysteme. Sogar einzigartige Ökosysteme wie Mangrovenwälder und Korallenriffe waren manchmal gefährdet. Jedoch wurden in den meisten iranischen UVBs biologische Auswirkungen nicht genügend berücksichtigt und nur in einer der untersuchten Kategorien stuften die UVBs biologische Auswirkungen höher ein als physikalisch-chemische. Biologische Variablen wurden in Monitoring-Plänen oft vernachlässigt, sogar in UVBs zu Anlagen mit einer hohen Gefährdung von Ökosystemen.

Obwohl die untersuchten UVBs wenig wirksam waren, fanden wir eine Tendenz zu Verbesserungen. Die Anzahl der identifizierten physikalisch-chemischen Auswirkungen und vorgeschlagenen Verminderungsmassnahmen nahmen zwischen 1996 und 2006 signifikant zu. Leider gibt es bisher keine solche Verbesserungstendenz für die biologischen Auswirkungen. Wir schliessen, dass Auswirkungen von grösseren Anlagen auf biologische Variabeln in allen Phasen einer UVP und allen Kapiteln eines UVB vermehrt berücksichtigt werden sollten.

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Hossein, Zurich, March 2009

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